AD-A113 741 AEROSPACE CORP GERMANTOWN MD ENVIRONMENT AND ENERGY --ETC F/G 13/2
MILITARY HAZARDOUS WASTES: AN OVERVIEW AND ANALYSIS.(U)
DEC 81 K E KAWAOKA, M C MALLOY, G L DEVER
UNCLASSIFIED ATR-81(8376)-1 NL

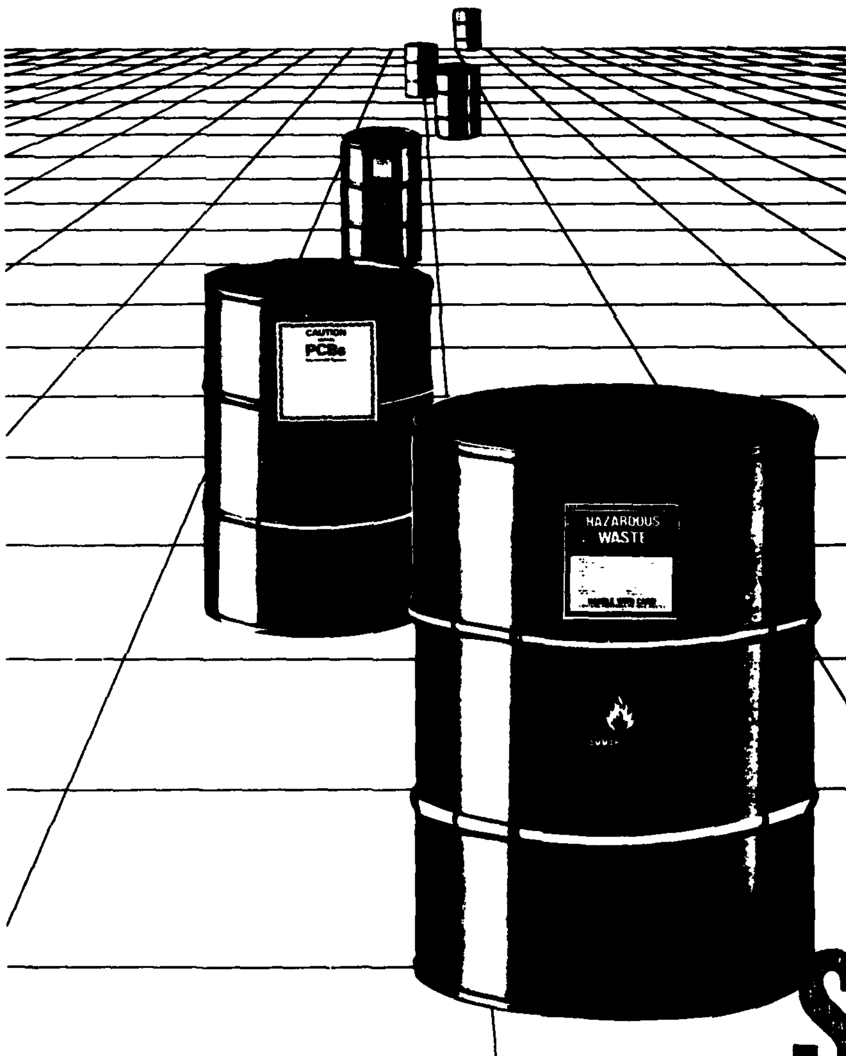
1 OF 2
AD
A113741

Aerospace Report No.
ATR-81(8376)-1

Military Hazardous Wastes: An Overview and Analysis

December 1981

AD A113741



82 04 23 007

Environment and
Conservation Directorate

The Aerospace Corporation

Accession For		
NTIS GRA&I	☒	
DTIC TAB	☐	
Unannounced	☐	
Justification		
By Per Ltr. on file		
Distribution/		
Availability Codes		
Dist	Avail and/or Special	
A		

Aerospace Report No.
ATR-81(8376)-1

**MILITARY HAZARDOUS WASTES:
AN OVERVIEW AND ANALYSIS**

Prepared by

K.E. Kawaoka, M.C. Malloy,
G.L. Dever, and L.P. Weinberger

December 1981

AN AEROSPACE CORPORATION SPONSORED RESEARCH PROJECT

Environment and Conservation Directorate
Eastern Technical Division
THE AEROSPACE CORPORATION
Germantown, Maryland 20874

Internally funded

Aerospace Report No.
ATR-81(8376)-1

MILITARY HAZARDOUS WASTES:
AN OVERVIEW AND ANALYSIS

Prepared by

Keith E. Kawaoka

Keith E. Kawaoka
Principal Investigator
Technology Impacts Directorate

Approved by

R. L. Johnson

A. D. Abbott

R.L. Johnson
Systems Director
Technology Impacts Directorate

A.D. Abbott
Principal Director
Environment and
Conservation Directorate

FOREWORD

This report presents the results of analyses completed during the period of October 1, 1980, through September 30, 1981, as part of the Aerospace Sponsored Research Program. The general objectives and emphasis of Aerospace Sponsored Research are to

- Provide scientific and technical advances that will form essential elements for planning and developing advanced systems
- Develop the analytical tools, technical facilities, and scientific and engineering expertise essential to the solution of critical system problems
- Develop a methodology for effective long-range macrosystem architectural planning -- for space systems in the context of military operations, for national security programs, and for related energy and environmental programs
- Maintain a dynamic link with Government, academic, and industrial research communities

This research project examines another vital aspect of military preparedness -- the protection of public health and the environment from hazardous wastes generated by the military. The safe and effective management of military hazardous wastes greatly enhances the quality of our lives and strengthens our national security.

The report describes and analyzes the management activities and motivating factors of the military in dealing with its hazardous waste streams. Findings and conclusions in areas of concern are given to provide information that may be of value to the future management of military hazardous wastes.

ACKNOWLEDGMENTS

The project team, consisting of K.E. Kawaoka, Principal Investigator, M.C. Malloy, G.L. Dever, and L.P. Weinberger, gratefully acknowledges the assistance and cooperation of a number of organizations and individuals in support of our efforts.

Invaluable information and substantial assistance were provided by agencies and offices of the Department of Defense and the Environmental Protection Agency, as follows: Defense (Office of the Deputy Assistant Secretary of Defense for Facilities, Environment, and Economic Adjustment; Defense Logistics Agency; and Defense Property Disposal Service); Army (Office of the Deputy for Environment, Safety, and Occupational Health; Materiel Development and Readiness Command; Toxic and Hazardous Materials Agency; Corps of Engineers; and Environmental Hygiene Agency); Navy (Office of the Chief of Naval Operations, Navy Material Command, Naval Facilities Engineering Command, Navy Supply Command, and Navy Energy and Environmental Support Activity); Marine Corps; Air Force (Air Force Headquarters, Logistics Command, and Engineering and Services Center); and the Environmental Protection Agency (Office of Solid Waste and the Industrial Environmental Research Laboratory, Cincinnati, Ohio).

The project team also expresses thanks to A.D. Abbott and R.L. Johnson of the Environment and Conservation Directorate for their technical supervision and guidance and to J. Meltzer, T. Iura, and D.R. Orozco of the Eastern Technical Division for their programmatic assistance and support.

CONTENTS

PRECEDING PAGE BLANK-NOT FILMED

CONTENTS (Continued)

CONTENTS (Continued)

EXECUTIVE SUMMARY

PROBLEM OVERVIEW

As the largest Federal buyer of hazardous materials (over 50,000 hazardous line items), the Department of Defense (DOD) is confronted with the management and disposal of increasing quantities of hazardous wastes at its over 700 major installations. The future buildup of defense activity will inevitably entail a further increase in the military hazardous waste inventory. In addition, recent Federal legislation has been established to strictly control the generation, handling, and transport of hazardous wastes; terminate dangerous dumping practices; and require the development of properly designed, operated, and accessible disposal facilities to ensure health and environmental protection. These developments have made the cradle-to-grave management of hazardous wastes DOD's highest environmental objective for the 1980s.

Although the nature and magnitude of the military hazardous waste stream are not completely known at present, DOD's activities are similar to the civilian sector's in terms of the type of industrial operations performed and unique by the nature of its strategic military operations. The overall size of the military community is comparable to the population of a large metropolitan area but is diffused into many installations of different sizes and locations. As in many civilian industrial and commercial sectors, DOD installations have often needed to adopt temporary practices due to the lack of suitable and accessible hazardous waste disposal sites. For example, many military installations have stockpiled wastes, such as DDT and polychlorinated biphenyls, to await the development of approved disposal options. The environmental and health consequences of these and other practices are potentially dangerous and may not be acceptable under new Federal and state regulations.

STUDY OBJECTIVES AND APPROACH

This independent Aerospace Corporation study has been conducted to determine the magnitude and scope of military hazardous waste problems and to identify and assess the DOD hazardous waste management approach and future needs. The study approach is designed to survey the current activities of DOD agencies involved with hazardous waste management operations and associated research and development

activities. Discussions were held with over 35 DOD policymakers, command and field managers, and technical experts to determine what they perceived as critical areas and appropriate management strategies. Regulatory issues and current research activities were discussed with Environmental Protection Agency (EPA) officials. These discussions were supplemented by a review of pertinent reports, memoranda, and regulations.

The following findings and conclusions are based on a review of DOD hazardous waste policies and a technical assessment of the compiled data. For a more detailed discussion and presentation of our recommendations made in response to these findings, refer to the report sections identified and Chapter 6 (Summary Findings and Recommendations).

SUMMARY FINDINGS AND CONCLUSIONS

GENERAL

DOD Is Required To Comply With All Federal, State, and Local Environmental Regulations

DOD compliance with environmental regulations is mandated by Executive Order 12088. In many instances, DOD is looked upon by the public as an example of Federal efforts in meeting environmental protection requirements (Sections 2.2, 4.3, and 6.3).

The Military Is at an Early Stage of Gathering Data on the Quantity and Characteristics of Military Hazardous Materials Procured and Wastes Generated

Problem definition and subsequent management solutions require an accurate characterization and inventory of the military hazardous waste stream. Regulatory requirements will also necessitate more accurate recordkeeping efforts. DOD, through the Defense Logistics Agency, recognizes the need for generation data and has initiated a DOD-wide hazardous material/waste survey (Sections 2.3 and 6.1).

The Identification of Hazardous Wastes and Associated Problems, Particularly at the Installation Level, Is Considered a Major Problem Among the DOD Components

The complexity of dealing with over 50,000 hazardous material line items is especially difficult at the installation level. Installation personnel are counted on to recognize, handle, properly package, and turn in hazardous wastes to the appropriate disposer. Often the identification instructions to installation personnel are not clear or sufficient (Sections 2.3, 3.2, and 6.1).

One of the Most Appropriate Solutions to the Hazardous Waste Disposal Problem Is Not To Generate Hazardous Wastes in the First Place

The reduction or elimination of hazardous waste generation at the source can be accomplished by reducing or substituting for the use of hazardous materials, better quality control, and in-process modifications. Although total waste generation cannot always be eliminated, total volume and potential hazard can be greatly reduced (Sections 5.1 and 6.1).

The Costs for Handling and Disposal of Military Hazardous Wastes Will Become an Increasing Economic Concern as Regulations Are Promulgated

Defense economic analyses will have to incorporate the costs of hazardous waste disposal as an integral part of any procurement system or capital project acquisition (Sections 2.2, 6.1, and 6.5).

POLICY AND REGULATIONS

RCRA Regulations Will Limit the Options for Disposal and Increase Administrative Costs

New regulations, such as the Resource Conservation and Recovery Act (RCRA), will significantly alter conventional disposal options and increase overall administrative costs. Hazardous waste regulations will introduce significant changes in the way DOD components use and operate with hazardous materials. The full impact has not been determined; however, indications such as more restrictive hazardous waste facility siting requirements and the need to properly manifest wastes signify changes in conventional operating procedures (Sections 3.2, 5.1, and 6.2).

Full Promulgation and Implementation of RCRA Regulations by EPA Are Expected To Require Another 5 to 10 Years

In the meantime, DOD, as a Federal agency, must comply with interim requirements set forth by EPA. The emergence of state-administered hazardous waste programs will further increase the variability and complexity of requirements for DOD (Sections 3.1 and 6.2).

MANAGEMENT AND OPERATIONS

DOD Policy on Hazardous Waste Management Has Been Developed; However, a Clearly Articulated Plan of Action To Guide Program Implementation Is Required

This implementation plan would describe overall program strategy, needs, methods, schedules, and resources for orderly implementation by

DOD components. Currently, the service branches must develop their own management systems to comply with the existing DOD policy guidance (Section 6.3).

Hazardous Waste Management Is an Integral Part of Military Environmental Programs, but Resource Limitations May Hinder Compliance Efforts

Although significant progress has been made to date to comply with hazardous waste regulations, military environmental protection programs, in general, must compete for resources with the primary military mission at each installation (Sections 4.3 and 6.3).

The Installation Commander Has Overall Responsibility for Complying With All Hazardous Waste Regulations

It is the overall DOD policy that the installation commander secure and maintain compliance with environmental regulations, including hazardous waste requirements. However, the Defense Property Disposal Service (DPDS) has the storage and disposal responsibility for all hazardous materials turned in to DPDS by the services for disposal (Sections 2.3, 4.5, and 6.3).

The Management System for Military Hazardous Waste Is Based on a Shared Responsibility Among the Various DOD Components

The military services are responsible for the (1) management of abandoned hazardous waste site cleanup, (2) cradle-to-grave management of exempted categories of hazardous material/waste under Defense Environmental Quality Program Policy Memorandum (DEQPPM) 80-5 (Section 4.3.2), and (3) management of other DEQPPM 80-5 waste categories up to the point of turn in to DPDS in segregated, properly labeled containers (see Figure 4-2) (Sections 4.3 and 6.3).

The Treatment, Storage, and Disposal of Hazardous Waste by Private Contract Is a Common and Preferred Alternative for DOD

This method avoids the construction and operation of waste facilities by the military on the installation. DOD is still responsible, however, for ensuring proper handling of wastes (Sections 4.3 and 6.3).

Technical Expertise To Implement DOD and Service Directives Is Not Always Available at the Installation Level

Training programs and expert technical assistance are vital for personnel engaged in the generation, handling, and disposal of installation hazardous wastes. The rapid development of technology and new requirements will necessitate the training of operations personnel in safe procedures. It can be expected that the competition for trained qualified personnel experienced in hazardous waste management will be very keen in the next few years (Sections 4.3, 4.4, and 6.3).

The Installation Restoration (IR) Program Is a Systematic Effort To Identify Inactive or Abandoned DOD Hazardous Waste Sites, Accidental Spills, and Other Detrimental Environmental Practices; To Define the Nature of the Problems; and To Institute Corrective or Preventive Measures

The results of the IR program to date could provide invaluable assistance to the national and state efforts to identify and clean up abandoned sites. The magnitude and extent of the remedial action required for past DOD disposal activities is uncertain at this stage (Sections 3.3, 4.3, and 6.3).

CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT

RCRA and Superfund Compliance Will Require Further Technological Development

Full compliance with hazardous waste regulations will require further control technology development. Conventional disposal options such as landfills or open burning/detonation of unstable explosive materials may be severely limited in the future. Research and development priorities for military hazardous waste pollution abatement must be identified and developed (Sections 5.1 and 6.4).

FUTURE OPPORTUNITIES AND NEEDS

The general consensus emerging from the study is that a management system for safely handling and controlling military hazardous wastes does exist, but must be further strengthened with adequate resources and budgets to meet the challenges imposed by RCRA and other hazardous waste regulations. Great uncertainty exists on the part of the general public and hazardous waste management officials alike concerning the degree and extent of hazard posed by these wastes and the level of management control required.

Based on the review and analysis of current military hazardous waste management programs, it is evident that DOD is taking positive steps to control and manage its hazardous wastes. Several initiatives

are now underway that should improve the military's ability to systematically address its hazardous waste problems. For example, the Installation Restoration Program will survey the extent of contamination at installations from past disposal practices. There is also every indication that DOD components are attempting to comply with hazardous waste management requirements. For example, DPDS actions required to implement most of the recommendations made in this report (Section 6) are currently planned or in process. However, despite these and other accomplishments, a great effort is still required to address this major and growing problem.

1. INTRODUCTION

1.1 OBJECTIVES

This study focuses on the number one environmental priority of the Department of Defense (DOD) -- the management of military hazardous wastes.* The study objectives are to (1) determine the magnitude and scope of military hazardous waste problems and (2) identify and assess the DOD hazardous waste management approach and future needs. The study is not intended to duplicate previous DOD hazardous waste study efforts, but uses and analyzes existing information in determining pertinent requirements for further development of the military hazardous waste management program.

1.2 SCOPE

The scope of the study has a DOD-wide emphasis; regional or installation-specific information is used for illustrative purposes only. In addition, the analysis of DOD hazardous waste management activities focuses on the continental United States. Information has been acquired on regulatory compliance requirements, the technical characteristics of hazardous waste management technologies, and the DOD hazardous waste management program. The study identifies the current military hazardous waste policy, planning, and management system. The current status of industrial control technology development is also assessed.

1.3 BACKGROUND

The issue of hazardous wastes emerged in the late 1970s as a major national health and environmental concern. In a highly industrialized

---

* For the purposes of this report, the term "hazardous waste" is defined by regulations developed under the authority of the Resource Conservation and Recovery Act of 1976 (P.L. 94-580, Section B.2.2). In general, a hazardous waste is any used or unused property, residue, byproduct, sludge, or other solid waste material that may cause or significantly contribute to serious illness or death or that poses a substantial threat to human health or the environment when improperly managed. The Environmental Protection Agency has established four characteristics to identify hazardous wastes: ignitability, corrosivity, reactivity, and toxicity. This report will not cover radioactive wastes, infective wastes, or the demilitarization of chemical warfare agents and munitions.

society, the number of people involved with hazardous waste is immense: over 750,000 businesses generate some amount of hazardous waste; over 10,000 transporters are involved in shipping it; over 30,000 sites are used to treat, store, or dispose of it; and there are an unknown number of "midnight dumpers" (transporters who take the wastes off generators' hands for a low price and then dispose of them illegally) (EPA, 1980e). The means by which hazardous waste can cause damage to public health and the environment are also numerous and include

- Pollution of groundwater
- Contamination of rivers, lakes, and other surface water
- Contamination of surface water sediments
- Pollution of air
- Combustion or explosion hazard
- Poison via the food chain
- Poison by direct contact

The Environmental Protection Agency (EPA) estimates that over 50 million metric tons of hazardous waste was generated in 1980 by U.S. industry (EPA, 1980d). That amount is projected to grow at a rate of about 3.5 percent a year, such that the annual hazardous waste generation may double by the year 2000. Although these current trends are alarming, the seeds of the problem were planted over 20 years ago, with the manufacture and widespread use of synthetic materials and the toxic and hazardous wastes subsequently generated.

Perhaps the most dramatic example of the effects of these "chemical time bombs" is the incident near Niagara Falls, New York, known as Love Canal. Many other disposal sites have been discovered throughout the country. EPA estimates that about 90 percent of the hazardous wastes generated in the United States are disposed of by environmentally unsound methods (EPA, 1980d).

To date, EPA has identified over 150 sites in the United States that have adverse impacts on public health or the environment. The list of sites is always under review and is updated. Each month, EPA identifies over 400 new potential sites that will require further evaluation and possible remedial action (GAO, 1981). Estimates range between 32,000 and 50,000 hazardous waste dump sites, of which 1200 to 2000 may pose significant health or environmental problems (Congress, 1979). Very few of these sites have been inventoried or properly surveyed to determine the potential risks. There are also an unknown number of sites produced as a result of unauthorized and indiscriminant "midnight dumping" of potentially hazardous wastes. The EPA Administrator, Anne Gorsuch, has stated that "the cleanup of hazardous waste sites under Superfund remains one of the Reagan administration's highest environmental priorities" (Gorsuch, 1981).

The Love Canal and the Valley of the Drums (Kentucky) incidents may represent only the tip of the hazardous waste iceberg (EPA, 1980a). EPA estimates that a total cleanup of potentially dangerous

abandoned or uncontrolled disposal sites could cost as much as $44 billion (GAO, 1981). Personal costs to people exposed directly or indirectly may never be fully determined.

The urgency of this national problem has significance to DOD. Being the largest Federal generator of solid and liquid waste, DOD is both similar to the civilian sector in terms of the type of industrial activities it performs and unique by the nature of its strategic military operations. The cumulative size of the DOD organization is equivalent to the population of a large metropolitan area.*

DOD possesses large quantities of hazardous material, both new items and waste products. All three service branches generate various types and quantities of hazardous wastes. Table 1-1 provides examples of hazardous wastes contaminating the area surrounding specific military installations. Monitoring and testing are continuing at these and other facilities, and in some cases, remedial cleanup operations are already occurring. For example, at the Army's Rocky Mountain Arsenal, to prevent the offsite migration of contaminated groundwater, corrective actions to date have consisted of using a bentonite barrier, dewatering wells, filtration, activated carbon, and reinjection wells. The magnitude and extent of the overall DOD and specific installation hazardous waste problems are still uncertain and not well quantified at present.

1.4 APPROACH

The study approach was designed to complement and supplement the activities of DOD agencies engaged in hazardous waste management, research, and development. This was done by defining the scope and status of military hazardous waste programs and assisting DOD decisionmakers by providing an overall analysis and assessment of military hazardous waste impact areas. The analysis and assessment of options are based on several information sources, including an intensive search and review of the applicable hazardous-waste-related literature. Data base sources included the Defense Documentation Center, Defense Logistics Agency (Alexandria, Virginia); Technology Support Center, U.S. Army Corps of Engineers (Huntsville, Alabama); U.S. Air Force Occupational and Environmental Health Laboratory (Brooks Air Force Base, Texas); Naval Energy and Environmental Support Activity (Port Hueneme, California); Offices of Solid Waste and Toxic Substances, U.S. Environmental Protection Agency (Washington, D.C.); Industrial Environmental Research Laboratory, EPA (Cincinnati, Ohio); RECON, U.S. Department of Energy (Washington, D.C.); and National Technical Information Service, U.S. Department of Commerce (Springfield,

---

* As of March 1981, the sum of active-duty military personnel and civilian personnel was approximately 3.1 million persons, excluding indirect hire and reserve personnel (DOD, 1981).

Table 1-1. Examples of Hazardous Waste Contamination of Specific Military Installations (Congress, 1981)

Installation	Mission	Examples of Hazardous Wastes Discovered in Groundwater
Picatinny Arsenal (Army), New Jersey	Research and development of all armament items. Also pilot plant production of explosives, propellants, metal parts, weapon assemblies, nuclear munitions, and radiological research materials.	Trichloroethylene (TCE), perchloroethylene (PCE), tetrachloraethylene, and other organics
Rocky Mountain Arsenal (Army), Colorado	Activities have included various chemical and chemical-filled munitions, chemical demilitarization, incendiary munitions, and pesticides manufacture (leased operation).	Diisopropylmethylphosphate (DIMP) -- a byproduct of GB manufacture, chemical warfare agent Dicyclopentadiene (DCPD) -- used in insecticide manufacture Organics (aldrin, endrin, dieldrin, dibromochloropropane (DBCP), carbontetrachloride, trichloroethylene, tetrachloroethylene, and others)
Lakehurst Naval Air Station/Naval Air Engineering Center, New Jersey	Research, development, test, and evaluation of naval air and weapon systems. Past activities include ordnance manufacture, airship operations, fleet and reserve helicopter squadron support, and aircraft training and testing.	Aviation fuel contamination, TCE, and other organics
Wordsmith Air Force Base, Michigan	Strategic Air Command facility	TCE

Virginia). In addition, direct contact was made by the project team with over 35 DOD offices involved in planning and policy direction, command management, field management, guidance support, and research and development.

During the information gathering and review work, we did not attempt to perform any analytical sampling and testing for various wastes, nor were any installation-specific surveys conducted. These efforts would have been resource-intensive and would not have materially affected accomplishment of the study objectives. Instead, we held discussions with policymakers, command managers, and technical experts within DOD to determine what were perceived to be critical problem areas and the current and future management strategies or activities.

We discussed regulatory issues and overall research strategies and state-of-the-art limits with EPA officials. These discussions were supplemented by a review of pertinent reports, regulations, and memoranda.

Section 2 of this report provides a current perspective on the DOD hazardous waste management program. Section 3 reviews the pertinent regulatory mandates governing various aspects of hazardous materials management and assesses the issues affecting the military. Section 4 describes the overall DOD philosophy, policies, management responsibilities, and organizations concerned with hazardous waste. Section 5 presents a technical review of hazardous waste control technology options and discusses their pertinent advantages and disadvantages. Section 6 identifies the major findings of the study and provides recommendations in determining future DOD waste management directions.

2. DEFINITION OF MILITARY HAZARDOUS WASTE MANAGEMENT NEEDS

2.1 NATIONAL AND DOD-WIDE PERSPECTIVE

Continuing studies have alerted the general public to the detrimental effects of hazardous wastes, even linking cancer and genetic mutations to some of the more potent chemicals. The introduction of additional exotic organic and synthetic chemicals to our normal daily lives has increased the quantity and diversity of hazardous materials in use and has complicated waste management efforts.

In addition, there is the almost daily discovery of landfills and dump sites where improper disposal practices have led to pollution of the environment. These instances, typified in the extreme by the Valley of the Drums and Love Canal, have resulted not from willful neglect but, for the large part, from lack of education and awareness of the potential effects of these hazardous wastes. Environmental pollution has resulted because in past decades these wastes were not recognized as harmful. Consequently, the disposal methods chosen were not designed to contain the pollutants for the long term, and the state of the art in disposal technology was not adequate to deal with them.

DOD currently maintains about 700 major installations worldwide and 376 in the continental United States, which generate various types and quantities of hazardous waste. Large industrial-type facilities, such as Army ammunition plants and depots, Navy shipyards, and Air Logistics Centers, generate the majority of the military hazardous wastes. Other facilities, for example, training or residential complexes, may produce smaller quantities of hazardous waste. Smaller facilities may also generate a variety of hazardous wastes from their operations.

The military also has a problem with past disposal sites that are polluting the environment. In fact, very few records were maintained that provide detailed accounts of hazardous waste disposal practices in the 1940s and 1950s (Marienthal, 1980). Under the current DOD policy, these problem sites are being dealt with on a priority basis. Notable among these are Rocky Mountain Arsenal (Colorado) and Redstone Arsenal (Alabama), where wastes from past chemical plant operations had migrated off-post and polluted nearby water resources.

The Air Force, Army, and Navy/Marine Corps face many of the same problems in managing their hazardous wastes, but there are a few substantial differences that should be noted. The Army manufactures most of the munitions for the rest of the service branches, an industrial operation that generates a large quantity of hazardous wastes (Maj. Tom Borkowski, U.S. Army Material Development and Readiness Command, Alexandria, Virginia, personal communication,

February 9, 1981). The Navy also produces some munitions, but this effort is confined primarily to load, assemble, and pack operations. The most unique aspect of naval hazardous waste management is not the types of wastes, but their generation and location (Carl Zillig, Office of the Chief of Naval Operations, personal communication, February 4, 1981). When large ships enter naval ports, they may be carrying wastes stored from over 3 to 6 months of sea duty. The unloading of the ship produces quantities of hazardous wastes that must be moved off the docks expeditiously because of severely limited storage space. The Air Force Logistics Command's most pressing hazardous wastes result from contaminated propellants and fuels and wastes from aircraft maintenance and rework facilities (Lt. Col. Charles Avery, Chief, Environmental Planning Division, U.S. Air Force Logistics Command, Wright-Patterson Air Force Base, Ohio, personal communication, April 22, 1981). Other Air Force operations, such as shop and fuel operations and laboratories, are also of concern. The Marine Corps' biggest hazardous waste generator is probably its motor pools and vehicle rework facilities, which are relatively small contributions compared to the larger Army and Navy industrial operations.

2.2 MOTIVATING FACTORS

2.2.1 Regulatory Mandates

There are three major Federal laws specifically addressing toxic and hazardous wastes, and these form the primary basis for all subsequent Federal, state, and local regulations and guidelines:*

- Toxic Substances Control Act (TSCA) of 1976
- Resource Conservation and Recovery Act (RCRA) of 1976 (as amended October 1, 1980)
- Comprehensive Environmental Response, Compensation, and Liability Act (hereafter referred to as Superfund) of 1980

TSCA deals primarily with chemical manufacturing and identification. RCRA is the centerpiece of legislation directed at solid waste management. In terms of hazardous wastes, RCRA, under Subtitle C, requires the identification and regulation of hazardous waste generators, transporters, storers, and treatment and disposal operators. Superfund has gone one step further in requiring the identification of past or abandoned hazardous waste disposal sites, with

---

* Other laws, such as the Clean Air and Clean Water Acts, also have limited provisions regarding hazardous wastes. An analysis of Federal hazardous waste legislation and regulations is presented in Section 3.

the objective of evaluating environmental contamination, defining liability, and initiating onsite cleanup, as necessary. In response to these laws, the military has divided its hazardous waste efforts according to similar responsibilities: current hazardous waste management (RCRA/TSCA) and past or abandoned hazardous waste sites (Installation Restoration).

2.2.2 Environmental Quality and Public Concerns

Environmental laws, such as TSCA, RCRA, and Superfund, are manifestations of the growing public concern over the quality of the environment. In addition, workers are becoming increasingly aware of dangers in their workplaces. By definition, the term "hazardous material" causes alarm among the general public and the work force. Thus, the scrutiny of public pressure is focused on hazardous waste management programs and is acutely applied to treatment, storage, and disposal options.

The military is responsive to concerns expressed by the public regarding hazardous wastes and has developed policy and management guidance to deal with such concerns. For example, DOD has set as a high priority the control of contamination and the prevention of offsite contaminant migration at military installations. This policy is already being implemented at several facilities where offsite contaminant migration has been confirmed or suspected. These include Rocky Mountain Arsenal (Colorado), Redstone Arsenal (Alabama), Pinebluff Arsenal (Arkansas), and Wordsmith Air Force Base (Michigan).

Despite these policies and efforts by DOD, public outcry and scrutiny appear to be inevitable. The extent of public concern is currently uncertain and will be largely dependent on the number of military installations found to pose a significant threat to the public health and environment.

2.3 EXTENT AND CHARACTERISTICS OF MILITARY HAZARDOUS WASTE MANAGEMENT NEEDS

2.3.1 Geographical

Military facilities are distributed throughout the United States and range from small recruiting stations to large troop-training and command bases to industrial-type manufacturing and repair facilities. These facilities vary in size from hundreds of square feet to hundreds of square miles in urban, suburban, and rural locations. Because of the dispersed location of these facilities and the distances between them, little cooperative or regional management of hazardous wastes from military facilities is possible; in fact, each military facility generally must manage its own wastes. In most cases, this means that the facility will rely heavily on private sector operators and/or nearby regional municipal systems for the treatment and disposal of wastes.

2.3.2 Command and Facility Differences

The differences in the types of military facilities and the hazardous wastes they generate strongly reflect the military mission of the major command that controls the facility. For instance, a troop-training base would not be expected to generate the quantity or diversity of hazardous wastes that a naval air rework facility would generate in the normal course of repairing and rebuilding aircraft. Some of the larger military bases contain several major commands as tenants, resulting in the generation of a more heterogeneous mixture of hazardous wastes. Sufficient data are not currently available to precisely characterize each specific military installation according to hazardous waste generation. In accordance with RCRA reporting requirements, DOD installations will be identifying and characterizing their waste streams.

2.3.3 Types of Wastes and Sources

Some military hazardous waste characterization data are available; however, the data are limited when describing the overall magnitude of the stream. For the most part, the requirements of RCRA, which addressed the need for control over hazardous waste use and disposal, had just been released by EPA or were in the process of being revised or formulated as this study was undertaken. In addition, although many military installations were involved with responding to RCRA reporting requirements, the data have not yet been tabulated by EPA or DOD.

In addition, hazardous waste management and emergency spill contingency plans are being developed for all military installations. Such plans will require a hazardous materials management survey, compiling information on hazardous materials characteristics (e.g., quantities, types, locations, generation rates) and current activity management practices. These plans will be revised and updated periodically (at least every 3 years) and should provide an accurate characterization of military hazardous waste streams for both individual installations and DOD as a whole.

Some installation-specific surveys have been performed at selected sites (Kraybill et al., 1980; AFESC, 1980). Hazardous waste types are, for the most part, similar to those generated by private industry. For example, hazardous waste produced by many Army arsenals and depots characteristically are closely related to waste from comparable civilian activities (Malone and Larson, 1980). Army depots involved in vehicle maintenance or the rebuilding of small arms typically have wastes associated with metal surface cleaning, paint stripping, and metal plating such as an automobile assembly facility might produce. Arsenals working with explosives and propellants produce wastes comparable to those from some sectors of the civilian chemical industry. Solutions to hazardous waste disposal problems that have been posed for civilian activities can, in many cases, be adapted to military operations. For

example, various treatment, recycling, and energy recovery technologies have been applied in the electroplating industry. Appendix A lists representative hazardous waste streams from military installations.

The Navy did a survey of its major installations a few years ago. The Navy hazardous waste generation rate was estimated at more than 18 million gallons of liquid wastes and 17 thousand tons of solids annually. Table 2-1 presents the estimated quantities of hazardous waste generated by six major Navy regions. These totals represent approximately 90 percent of the Navy and Marine Corps installations with industrial operations (NEESA, 1978). No comparable surveys were available for the Army or Air Force.

The types of hazardous waste categories generated at various types of naval facilities are listed below (NEESA, 1978).

- Shipyards
  - Sandblast wastes: organotin and copper compounds
  - Asbestos
  - Otto fuel
  - Toxic hydraulic fluids
  - Boiler blowdown wastes: hydrazine, morpholine
  - Mercury and other metals
- Weapons Stations
  - Explosives manufacturing wastes
  - Propellant wastes
  - Obsolete munitions
- Fuel Depots
  - Tank bottoms
  - Waste fuels
  - Oils
- Air Rework Facilities
  - Metal plating wastes
  - Solvents
  - Degreasers
- Disaster Preparedness Units
  - Decontaminating agents
  - Supertropical bleach
  - Chemical warfare decontamination (DANC, DS_2)

Although the industrial-type operations on military bases contribute the greatest amount of hazardous wastes, a survey conducted by the U.S. Army Corps of Engineers' Construction Engineering

Table 2-1. Annual Navy Hazardous Waste Types and Quantities (NEESA, 1978)

Region	Hazardous Waste Type										Totals	
	Paints, Solvents (10^3 gal)	Hydraulic Fluids (10^3 gal)	Indust. & Oil Sludge (tons)	Ordnance (tons)	Plating Acids/Caustics (10^3 gal)	Pesticides (10^3 gal)	Decont. Materials (tons)	Fire Agents (10^3 gal)	Misc. Solids (tons)	Misc. Liquids (10^3 gal)	10^3 kg	tons
Northern	2012.4	286.9	464.9	3.0	754.1	37.7	69.8	18.6	1210.8	655.3	3765.0	1748.5
Chesapeake	125.7	57.6	15.2	860.0	52.2	6.0	18.5	2.0	99.4	127.5	371.0	993.1
Atlantic	554.8	280.9	593.6	35.0	445.1	22.6	38.3	50.2	2516.3	595.0	1948.6	3183.2
Southern	2265.9	472.7	1698.8	183.0	824.9	44.9	84.4	56.8	2371.9	1205.2	4870.4	4338.1
Western	1958.8	614.7	1829.5	55.0	1356.8	65.2	264.0	87.1	4066.5	1739.6	5822.2	6215.0
Pacific	388.4	330.3	575.0	18.0	237.3	34.8	149.5	17.3	232.0	404.7	1412.8	974.5

Totals: 18,602,300 gallons of liquid
17,545 tons of solids

Research Laboratory (CERL) demonstrated that multipurpose troop facilities cannot be overlooked in the management scheme (Kraybill et al., 1980). The CERL study of two unidentified FORSCOM (U.S. Army Forces Command) installations and a major Army hospital revealed a wide variety of hazardous materials/wastes generated on the bases, although usually found in small quantities. The six major categories of wastes that were identified at these facilities were

- Waste oil/petroleum, oil, and lubricant products
- Solvent tank bottom sludges
- Paint wastes
- Pesticides
- Polychlorinated biphenyls (PCBs)
- Medical/infectious wastes

As a result of this effort, CERL developed a matrix of facility operations (e.g., motor pool, paint shop, fire department) and general categories of hazardous materials/wastes that might be used at those locations (Table 2-2). This matrix was developed as an aid to ensure that facility surveys are conducted in a comprehensive manner, but it is also useful as an indication of the variety of wastes generated by these types of installations.

2.3.4 Existing Disposal Systems

The disposal responsibility for hazardous waste rests with each individual installation, under the direction of the installation commander. Hazardous wastes currently being generated are disposed of (by incineration and landfill burial) primarily by service contract with commercial sources. Depending on the particular type of hazardous waste involved, disposal responsibility could include the installation commander and the Defense Property Disposal Service of the Defense Logistics Agency. Section 4 further describes these responsibilities.

Pending and future RCRA hazardous waste management regulations may further limit disposal options and increase administrative costs for tracking to ultimate disposal. For example, open burning/detonation of unstable explosive materials may no longer be permitted under future RCRA regulations, and suitable alternative technology does not exist to accommodate the vast majority of ordnance waste generated. Acceptable land for ultimate disposal of hazardous waste may be limited in the near future because of tighter licensing requirements, higher costs, and greater demand for disposal services. Some regions of the country are already experiencing such effects (EPA, 1980f). These and other factors adversely affect the military in its attempt to comply with regulations while faced with the spiraling costs of handling, processing, and disposal charged by contractors.

Table 2-2. Potential Hazardous Wastes Generated by Military Operations (Kraybill et al., 1980)

Facility Operation	Hazardous Waste Type												
	Solvents	Lubricating Oil	Hydraulic and Cutting Oil	Paint Waste	Solvent Tank Bottoms	Toluene Diisocyanate	Leachate From Hazardous Waste Landfill	Electroplating Sludge	Insecticides, Pesticides, etc.	Hospital-Type Waste	Decontaminating Agents	Miscellaneous Chemicals	POL-Contaminated Soil
Vehicle Rebuilding	•	•	•	•	•							•	•
Vehicle Maintenance	•	•	•	•	•							•	•
Motor Pools	•	•	•	•	•							•	•
Troop Units	•	•	•	•	•							•	•
Sanitary Landfill	•	•	•	•	•	•	•		•	•	•	•	•
Entomology Shop									•				
Packing Shop						•							
Paint Shops	•			•								•	
Hospitals and Clinics	•									•		•	
Laboratory Facilities	•									•		•	
Heating and Cooling Plant												•	
Fire Department		•										•	•
Aviation Maintenance	•	•	•	•	•							•	•
Industrial Waste Treatment Plant		•	•	•									
Sewage Treatment Plant												•	
Laundry Facilities	•											•	
Petroleum Oil Lubricants Yard	•	•	•	•									•

3. REGULATORY REVIEW AND ANALYSIS

3.1 REVIEW OF APPLICABLE LAWS AND REGULATIONS

The problems of solid waste management were initially addressed in 1965 by the Solid Waste Disposal Act and in 1970 by the Resource Recovery Act. These acts essentially placed the responsibility for handling waste with the states and provided EPA with funds to promote resource recovery. In the 1970s, other environmental laws, such as the Clean Air Act (CAA), Clean Water Act (CWA), Safe Drinking Water Act (SDWA), and Occupational Safety and Health Act (OSHA) addressed limited aspects of the hazardous waste problem. For example, the Clean Air Act attempted to regulate the emission of certain hazardous air pollutants, and the Clean Water Act attempted to regulate discharges of toxic and hazardous waste into the Nation's waterways.

It was not until the passage of the Resource Conservation and Recovery Act (RCRA) in 1976, however, that the first comprehensive Federal effort to deal with the specific problem of hazardous waste was initiated. The Toxic Substances Control Act of 1976 (TSCA) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) added new regulations to manage waste, and Executive Order (E.O.) 12088 (1978) required all Federal agencies to comply with all regulations.

These laws were prime motivating factors for the development of a hazardous waste management program by DOD. These laws also contain enforcement procedures including severe penalties, such as $25,000 a day for noncompliance with RCRA. Additionally, the National Environmental Policy Act (NEPA) of 1970 charged all Federal agencies, including DOD, with the responsibility for protecting the environment. NEPA mandated that Federal agencies evaluate the potential impacts of their actions on the environment and implement mitigating measures, if possible.

A summary of the major Federal hazardous waste laws, their implementing regulations, and their requirements for DOD hazardous waste management are provided in Appendix B (Table B-1). It must be noted that all regulations and laws cannot be covered in this report because the regulations are numerous and detailed, many are still evolving, and the interrelationships between some regulations have still not been defined by the implementing agencies.

An analysis of the major regulatory issues and the implications for DOD are presented below. The important issues created by each major law are identified and analyzed in terms of the significance to DOD,

potential ramifications and effects, and possible alternative options for dealing with the issues.

3.2 RESOURCE CONSERVATION AND RECOVERY ACT

3.2.1 Background

RCRA is the major legislation governing the management of solid waste. Subtitle C of RCRA is specific to the management of hazardous waste and concerns the management of hazardous wastes from the "cradle" (the point of waste generation) to the "grave" (the point at which the waste is finally disposed of). Tracking hazardous wastes is accomplished by requiring reports from waste generators and those involved in the treatment, storage, and disposal of waste and by a manifest system, i.e., the requirement for signed and documented shipping papers that accompany wastes during transport from the point of generation to the designated treatment, storage, or disposal facility. The major sections of the regulations implementing Subtitle C are summarized in Appendix B (Table B-1).

3.2.2 What Are Military Hazardous Wastes?

To determine when a material becomes a hazardous waste, strict adherence to the congressional definitions of solid waste and hazardous waste should be considered. A flow chart depicting the procedural steps for defining solid and hazardous wastes and the need for compliance with Subtitle C of RCRA is presented in Figure 3-1.

A solid waste, as defined by RCRA, is "any garbage, refuse, sludge, or . . . solid, liquid, semi-solid or contained gaseous material, resulting from industrial, commercial, mining or agricultural operations, or from community activities which: (1) Is discarded or is being accumulated, stored or physically, chemically or biologically treated prior to being discarded; or (2) Has served its original intended use and sometimes is discarded; or (3) Is a manufacturing or mining by-product and sometimes is discarded." Certain waste materials are excluded because EPA does not consider them solid wastes (Appendix B).

After the responsible DOD agency has determined that the material is a solid waste, it must determine whether it is hazardous. If the waste is listed as hazardous in 40 CFR 261, the determination is straightforward. If, however, the waste is not listed, the agency should have the waste tested for the four characteristics of hazardous wastes: ignitability, corrosivity, reactivity, and EP (extraction procedure) toxicity. A waste need only meet the criteria under one test to be hazardous; however, all four tests should be conducted so that safe handling practices can be exercised and a complete waste description given in the annual report to EPA. Under Defense

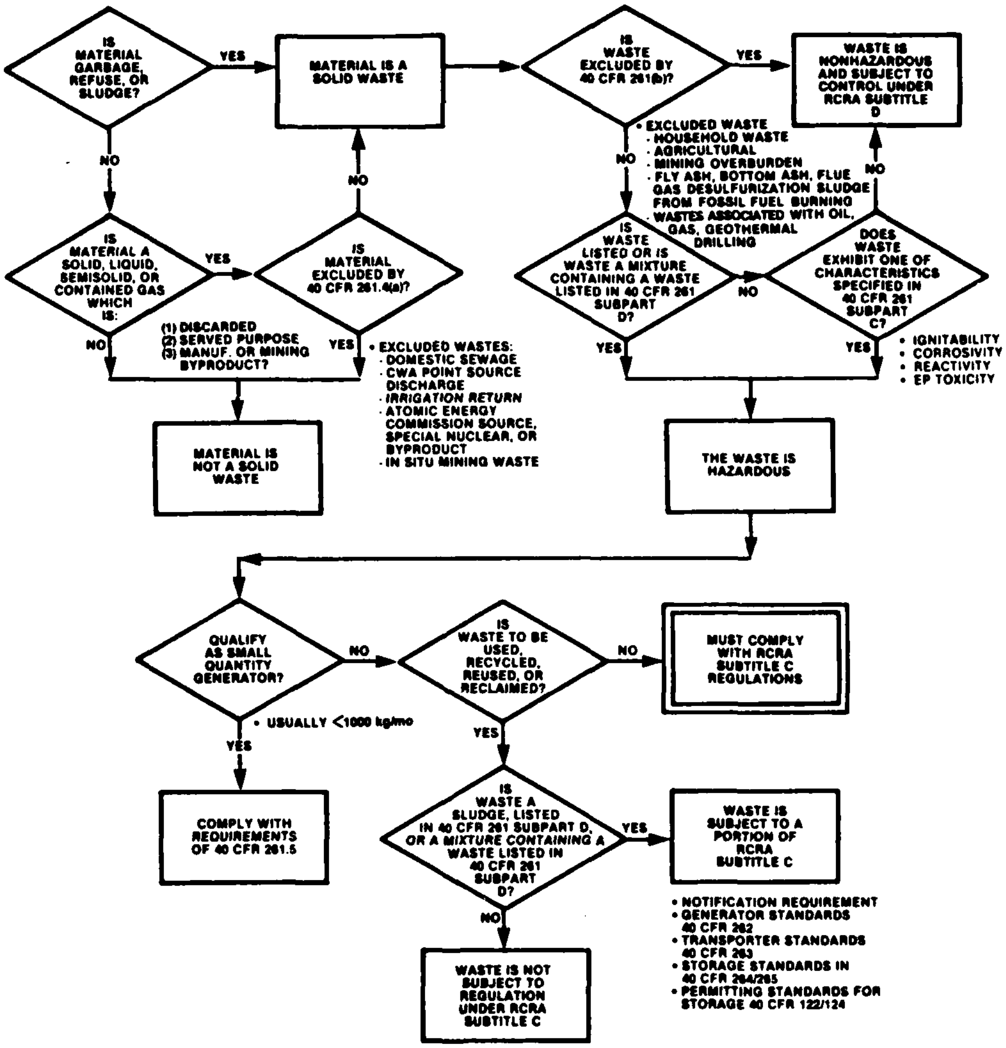


Figure 3-1. Procedural Steps to Determine Applicability of RCRA Subtitle C Regulations

Environmental Quality Program Policy Memorandum 80-5, certain items are excluded from disposal guidelines (see Section 5, Table 5-5).

3.2.3 Are Treatment, Storage, and Disposal Sites Available for Military Hazardous Wastes?

The availability of treatment, storage, and disposal (TSD) sites for DOD wastes is an important issue because DOD generates a large quantity of diverse hazardous waste streams. RCRA regulations require that all hazardous waste TSD facilities obtain a permit to operate. Existing TSD facilities are those that were operated or constructed prior to November 19, 1980.

New TSD facilities are those constructed after November 19, 1980, and they are subject to the standards promulgated in 40 CFR 264. In some cases, these standards are more stringent than those governing existing facilities. For example, new incinerators must meet a destruction and removal efficiency of 99.99 percent; existing incinerators are not yet required to meet this performance standard. Final standards have not been promulgated for some facilities, such as landfills, disposal piles and impoundments, and underground injection facilities. EPA has indicated that it may take 3 to 5 years to finally issue permits to facilities currently operating under the interim status standards.

Although DOD has many of its own storage facilities across the Nation, it generally relies on outside service contractors for treatment or ultimate disposal of its hazardous waste. A recent study (EPA, 1980f) indicates that there may be shortages of certain types of hazardous waste TSD facilities within the next 2 years in several EPA regions. Costs for treatment and disposal may rise; in some areas, there may not be any approved disposal facilities available, thus forcing DOD to store increasing quantities of hazardous waste. The problem may be further aggravated because new hazardous waste TSD facilities may not be built quickly enough to handle the demand. Siting constraints, high costs, and facility design problems, along with the opposition of the general public to hazardous waste management facilities, act to impede approval and permitting of new facilities. Possible solutions to this problem include reducing waste volumes; recycling wastes; and constructing onsite DOD waste handling, storage, and disposal facilities. The latter solution is not considered a viable option for hazardous materials and wastes handled by the Defense Property Disposal Service (DPDS). Disposal will be accomplished by service contract with commercial sources in accordance with Federal procurement regulations and Federal, foreign, state, and local environmental laws and regulations.

3.2.4 When Is DOD Liable for Military Hazardous Waste?

DOD is unquestionably responsible for the proper management of a hazardous waste as long as it is in a DOD TSD facility or is being transported by DOD. Questions of liability arise when a DOD hazardous waste generator uses a private offsite hazardous waste TSD

facility. The question of generator liability has not and cannot be answered by EPA because neither RCRA nor Congress gave EPA the power to address the issue clearly. When a TSD facility is found to be in noncompliance with RCRA standards and regulations, the courts will determine, on an individual basis, whether or not the generator is responsible (EPA, 1980b).

The issue of liability is important to DOD generators who use offsite TSD facilities because, if DOD is found liable, severe penalties, fines, and cleanup expenditures may be levied on DOD. In addition, being implicated in a case that discloses negligence and environmental damage on the part of DOD creates bad public relations. By directing DOD officials to keep careful records of their waste handling operations, use proper manifests, and periodically track and audit their offsite transporters and TSD facilities, DOD can minimize its potential for liability problems.

3.2.5 How Are Mixtures of Nuclear and Hazardous Wastes Handled?

The definition of a hazardous waste specifically excludes nuclear wastes that are regulated by the Atomic Energy Act of 1954 as amended; however, the regulations do not indicate how mixtures of hazardous and nuclear wastes are to be managed. By definition, such a mixture is hazardous and subject to RCRA regulations; however, because the regulations governing nuclear wastes are more stringent than RCRA regulations, it appears that the nuclear waste regulations would take precedence.

Because there are no guidelines, standards, or regulations governing the management of mixtures of nuclear and hazardous waste, DOD should prepare its own guidelines for managing such mixtures. These guidelines should be coordinated with the Nuclear Regulatory Commission (NRC).

The nature of military operations makes the probability high that DOD would encounter mixtures of nuclear and hazardous wastes at some of its facilities. DOD should determine if any such mixtures occur on DOD sites and assess the possibility of segregating the wastes before they are mixed. Where segregation cannot be accomplished, DOD should manage the wastes under NRC regulations. This will ensure that the wastes are handled under the most stringent regulations, and there should be no need for duplicating efforts by trying to comply with RCRA regulations at the same time.

3.2.6 How Does State Primacy of the Hazardous Waste Management Program Affect DOD?

Section 3006 of RCRA states that the management of hazardous waste is a state responsibility. EPA's program is to provide the states with a basis from which to develop their management plans. The state

programs must be equivalent to, but may be more stringent than, EPA's program. A summary of the status of approved states is presented in Appendix B.

With military facilities in all 50 states, DOD will be responsible for complying with all EPA-approved state hazardous waste management programs. As various states submit program plans for approval, revise and amend programs, and assume responsibility for programs, DOD installations will have to continually monitor the state's program approval application to EPA in their respective states. Maintaining close contact with state and regional EPA officials involved with hazardous waste management will assist DOD in maintaining knowledge of emerging plans and evaluating how best to comply with different state regulations. Monitoring responsibilities will increase the need for additional technical staff.

3.2.7 What Future EPA RCRA Regulations Are Important for Managing Military Wastes?

EPA has stated in the preamble to the final regulations implementing Subtitle C of RCRA that the agency shall continue to promulgate additional regulations throughout the decade (EPA, 1980c). Such regulations are expected to include the management of small hazardous waste generators and recycling/recovery operations. Standards will also be set periodically for specific types of TSD facilities. Hazardous waste regulations proposed or promulgated since May 1980 are shown in Appendix B (Table B-2). A recently published EPA agenda indicates a number of anticipated changes and additions for RCRA regulations (EPA, 1981). A summary of these proposed changes is also included in Appendix B (Table B-4). Because additional regulations and revisions are expected throughout the decade, DOD must remain aware of emerging regulations, assess the impact of each new regulation on DOD operations, and ensure timely compliance with the regulations.

3.3 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (SUPERFUND)

3.3.1 Background

Superfund was enacted on December 11, 1980, and establishes broad Federal authority to respond to releases or threats of releases of hazardous substances from vessels and facilities. Under Superfund, the Government may take remedial or removal action whenever there is a release or a substantial threat of a release of contaminants that may present a danger to public health or welfare (Section 104). The National Contingency Plan (NCP) is to be revised to reflect the new statutory authorities and, after the revision, response activities are to be performed (Section 105). Section 107 makes it clear that owners and operators of facilities from which a release has occurred, as well as

other persons who contributed to the problem, shall be liable for clean-up costs and damages to the natural and human environment.

Congress, being especially concerned with potential environmental and health problems associated with facilities that treat, store, or dispose of hazardous substances, recognized that there is a lack of information on these sites. Therefore, in Section 103(c), Congress provided that

> Within one hundred and eighty days after the enactment of this Act, any person who owns or operated or who at the time of disposal owned or operated, or who accepted hazardous substances for transport and selected a facility at which hazardous substances (as defined in Section 101(14)(C) of this title) are or have been stored, treated, or disposed of shall, unless such facility has a permit issued under, or has been accorded interim status under, subtitle C of the Solid Waste Disposal Act, notify the Administrator of the Environmental Protection Agency of the existence of such facility, specifying the amount and type of any hazardous substance to be found there, and any known, suspected, or likely releases of such substances from such facility.

The purpose of the notification was to assist EPA in developing an inventory of hazardous waste sites and to facilitate the development of priorities for investigation and possible response action. The notification received will complement EPA's ongoing site discovery and investigation program.

3.3.2 What Is the Significance of Superfund to Military Wastes?

Section 103(C) of Superfund requires any person who has owned or operated a hazardous waste TSD facility, or who has accepted hazardous substances for transport to a TSD facility, to send a completed EPA Form 8900-1 to EPA by June 9, 1981. Form 8900-1 is to be used to notify EPA of old, abandoned, or unpermitted hazardous waste TSD facilities. Facilities that are currently operating under a permit or have been accorded interim status under Subtitle C of RCRA do not need to be identified on Form 8900-1 because they are currently listed with EPA. The act states that any person who knowingly fails to notify EPA of the existence of such a facility may be fined, upon conviction, not more than $10,000 or imprisoned for up to 1 year, or both.

DOD has been generating and handling hazardous wastes for many decades, and has thus owned and operated a large number of TSD sites that are no longer operating. Under Superfund, DOD is responsible for identifying these old, abandoned hazardous waste sites and

notifying the appropriate Regional Administrator of EPA. In some cases, the land has already been sold or used for other purposes, and records are old and often incomplete. Even so, Section 103(c) requires the person who owned the site at the time of disposal to notify EPA. DOD is therefore required to submit information to EPA on excessed sites where hazardous wastes were stored or disposed of.

DOD continues to operate the Installation Restoration (IR) program to identify sites on current military property, assess their contamination, and evaluate the need for control and cleanup activities. DOD has established priorities for cleaning up leaking, contaminated sites to control only offsite migration and contamination. The inventory of former DOD excess site properties will also have to be included in the IR program, in accordance with EPA's reporting requirements. Additionally, the administration has recently delegated to DOD all authority to monitor and enforce its own facilities.

DOD has acknowledged that it recommended to the Office of Management and Budget that DOD be given on-scene coordinating responsibility for its own installations. However, in hearings before a subcommittee of the Senate Environment and Public Works Committee (July 20, 1981), some state and local representatives indicated that they felt DOD is uncooperative in cleaning up wastes. They expressed concern about groundwater contamination and contaminant migration, and indicated that DOD should not be allowed to monitor its own facilities. DOD, on the other hand, stated that because DOD knows more about its own activities than EPA or the states, DOD should have on-scene coordinating responsibility for its own installations. DOD also stated that its policy is to ensure that off-post migration does not occur. In E.O. 12316 of August 14, 1981, President Reagan delegated authority for managing and controlling hazardous releases from DOD facilities or vessels to the Secretary of Defense. The order states that DOD is a member of the national response team, designates DOD as a Federal trustee for natural resources, and assigns DOD on-scene responsibilities.

3.4 TOXIC SUBSTANCES CONTROL ACT

3.4.1 Background

The Toxic Substances Control Act was enacted by Congress in 1976 and became effective January 1, 1977. It authorizes EPA to conduct the following four activities.

Section 8(a) authorizes EPA to require manufacturers or processors of chemical substances to report the chemical to EPA. The information is to be used in developing and maintaining a chemical substances inventory (Section 8(b)). It is important to note that the chemical inventory is not a list of toxic or hazardous chemicals, but a listing of all existing chemicals by their specific chemical names. It is also

important to remember that TSCA requirements extend only to chemicals used for commercial purposes. Research and development chemicals are not covered until introduced into the marketplace.

Section 4 authorizes EPA to promulgate rules establishing testing procedures and the conduct of health and safety studies. Congress determined in TSCA that adequate information should be developed on how chemicals affect health and the environment, and that those who manufacture and process commercial chemicals should be responsible for developing this information. EPA can issue rules requiring industry to test particular chemicals, and can issue testing standards specifying the procedures to be used in conducting tests for certain health and environmental effects.

Section 5(a) authorizes EPA to collect information from those intending to introduce a chemical substance not already on the inventory into the marketplace at least 90 days before they begin manufacture. This is known as the premanufacturing notification form (PMN).

Section 6 provides EPA with the authority to establish regulations to control the manufacture or processing of chemical substances that may present a significant hazard to human health or the environment. After considering information submitted on the PMN, EPA can take one of the following actions:

- No action (i.e., the product may be released to market without restrictions)

- Regulate the substance until additional health and environmental data are made available to permit an evaluation of the chemical's effects

- Prohibit or regulate the manufacture, processing, distribution, use, or disposal of the new chemical, if the new chemical poses an unreasonable risk to health or the environment

- Propose rules requiring the manufacturer and others to report "significant new uses" or other changes in exposures and releases, if immediate regulation is not necessary but if EPA believes that future increases in exposure may cause concerns

- Refer the chemical to other EPA programs or other Federal regulatory agencies that have specific jurisdiction for such chemicals

Under Section 6(e), TSCA specifically calls out polychlorinated biphenyls (PCBs) and declares that they be regulated stringently. Under this provision, EPA has banned the manufacture, processing, distribution, and use of PCBs. Anyone violating any requirement of this law is subject to penalties or fines up to $25,000 for each day of violation, 1 year in prison, or both. EPA is authorized to inspect

chemical manufacturing, processing, and storage facilities and to subpoena witnesses and documents to enforce TSCA.

3.4.2 How Should the Military Dispose of Waste PCBs?

Because Congress specifically required EPA to regulate the production, distribution, use, and disposal of PCBs under TSCA, the handling of military PCBs must be accomplished according to specific regulations (40 CFR 761) prepared under TSCA's authority. The military currently has large quantities of waste PCBs that should be disposed of either in approved incinerators that maintain a destruction and removal efficiency (DRE) of 99.9999 percent of the PCBs or by a chemical destruction processes when approved by EPA. Disposal of PCBs is a DPDS responsibility. DPDS has awarded several contracts involving millions of dollars to dispose of DOD PCB items worldwide. This reliance on commercial disposal services represents an initial thrust of disposing of all DOD PCB items by DPDS.

EPA is currently considering ways of integrating the PCB disposal requirements into RCRA (Ed Martin, EPA, personal communication). Such a move would decrease the number of regulations and would place the management of PCBs under the law that specifically addresses all hazardous wastes, RCRA. However, there are several factors that make integrating the regulations difficult. First, incinerators regulated under RCRA need achieve a DRE of only 99.99 percent, while incinerators burning PCBs under TSCA regulations must achieve a DRE of 99.9999 percent. A decision must be made as to whether the DRE of 99.9999 percent should be kept for PCBs under RCRA or whether the lower DRE of 99.99 percent would be acceptable. Proponents of the lower DRE argue that wastes more hazardous than PCBs, such as dioxins, are regulated under the lower DRE. Opponents argue that the more stringent DRE provides greater protection and, because it was set specifically for PCBs, should be maintained. A compromise within EPA on this issue may require some time.

DOD should recognize that PCB regulations from TSCA may be integrated into RCRA in the future and that the integration may affect the degree to which PCBs must be destroyed. Until that time, the handling of PCBs will be regulated under TSCA, and DOD should comply with the existing regulations of 40 CFR 761.

3.5 OTHER ENVIRONMENTAL LAWS

3.5.1 Background

Since 1970 and passage of the National Environmental Policy Act, Congress has passed and amended many environmental laws. Of the many laws, the Clean Air Act, Clean Water Act, Safe Drinking Water Act, Occupational Safety and Health Act, and Hazardous Materials Transportation Act (HMTA) each address some aspect of hazardous waste management.

CAA regulates emissions of certain hazardous air pollutants through its National Emissions Standards for Hazardous Air Pollutants (NESHAPS). Under CAA, standards have been set for emissions of asbestos, beryllium, mercury, and vinyl chloride. Radionuclides and benzene are listed as hazardous; however, no NESHAPS have been published for either substance.

CWA regulates hazardous materials spills and discharges of hazardous pollutants into surface waters. Regulations 40 CFR 116 and 117 designate hazardous materials, indicate reportable quantities of these substances when spilled, and assess penalties for spills. Regulation 40 CFR 151 requires the preparation of a Spill Prevention, Control, and Countermeasure (SPCC) Plan for facilities subject to National Pollutant Discharge Elimination System (NPDES) permitting requirements. The SPCC plan is oriented toward the prevention of hazardous materials spills. An NPDES permit is required for point source discharges into waters of the United States. In addition to SPCC plans, Best Management Practice Plans are required of NPDES-permitted facilities (40 CFR 125). These plans contain engineering plans for treatment requirements; operation and maintenance procedures; scheduling; prohibitions; and practices to control site runoff, spills, sludge and waste disposal, and drainage from storage areas.

SDWA regulates underground injections of substances by setting standards for different waste types and injection well types and by requiring an underground injection control permit to construct and operate an injection well. Standards are oriented toward ensuring that wastes do not leak into underground sources of drinking water that are currently used or have the potential to be used as a public drinking water supply. Specific standards are given in 40 CFR 146 for wells injecting hazardous waste.

OSHA specifies worker health standards within the workplace. OSHA standards also prescribe safety equipment, handling procedures, monitoring, recordkeeping, and safe exposure limits for hazardous materials.

HMTA authorizes the Department of Transportation (DOT) to establish regulations governing the transport of hazardous materials. These regulations define hazardous materials and prescribe labeling, marking, and placarding requirements for such material, in addition to reporting requirements for spills and accidents. Congress required EPA and DOT to work together in developing regulations governing the transport of hazardous waste. The final RCRA regulations integrate the existing DOT regulations (49 CFR 171-179) with EPA regulations (40 CFR 262 and 263) by requiring the use of the established DOT labeling, marking, placarding, and container rules by hazardous waste transporters. Accidents and spills that occur during transport are reported to DOT.

3.5.2 What Is the Relationship of These Other Environmental Laws to the Management of Military Hazardous Wastes?

Hazardous pollutants do not always lend themselves to being treated, stored, or disposed of in an RCRA facility. In such cases, the release of these pollutants is controlled through laws and regulations other than RCRA. For example, a munitions factory may generate some emissions that are released through a stack. Emissions of any of the four hazardous emissions controlled under NESHAPS must be permitted in accordance with CAA. These emissions would not be regulated under RCRA because, although the emissions are hazardous pollutants, the gases are not containerized. Another example is a hazardous waste incinerator that emits sulfur dioxide. The incinerator must not only be permitted as a hazardous waste treatment facility under RCRA, but the emission of more than 250 tons of sulfur dioxide per year must be permitted under CAA.

The relationship between hazardous waste and CWA is similar to that with CAA. Point source dischargers into water bodies must receive an NPDES permit that specifies requirements such as degree of treatment and allowable concentration of discharges. For example, an Air Logistics Center may generate a wastewater stream that contains some of the hazardous materials listed by CWA; however, the waste stream may not be hazardous after being tested under the four RCRA criteria (ignitability, corrosivity, reactivity, EP toxicity). If this waste stream receives some treatment and is discharged to a local water body, the discharge of the hazardous constituents may be regulated by the NPDES permit alone. On the other hand, if the waste stream meets one of the tests for being hazardous, the treatment facility would have to be permitted under RCRA as a hazardous waste treatment facility, and the discharge would also require an NPDES permit.

The disposal of military hazardous wastes into the ground via an injection well must be accomplished according to the standards (40 CFR 146) promulgated under SDWA. The construction and operation of the well and injection system must also receive an underground injection control permit. The aboveground facilities that deal with storage or treatment of the waste prior to the injection require an RCRA permit.

Military facilities at which hazardous materials are handled must also comply with appropriate OSHA standards. The workplace environment and the safety equipment should meet OSHA standards; however, a permit is not needed. OSHA representatives periodically inspect military contractor facilities for compliance, and fines may be levied for noncompliance.

The relationship between hazardous waste and the DOT hazardous materials transportation regulations are clearly indicated in RCRA regulations 40 CFR 262 and 263. Marking, placarding, and labeling of hazardous wastes are to be performed in accordance with DOT regulations. The information on the manifest corresponds to information required by a standard DOT shipping document, and containers must

meet DOT regulations. Accidents and spills occurring during transport are reported to DOT, which is responsible for notifying EPA of the spill. The integration of DOT and EPA regulations for managing hazardous waste transportation has resulted in no duplication of regulations.

Determining the need for various environmental permits can become confusing for an installation or base commander faced with a myriad of Federal and state permit requirements. Maintaining a staff of planners, environmentalists, and engineers with experience in identifying and obtaining permits is essential but not always feasible for an installation. Encouraging cooperation and communication among DOD and EPA regional offices and state and local agencies will assist DOD in identifying the necessary permits and in maintaining an awareness of proposed regulations.

4. MILITARY HAZARDOUS WASTE MANAGEMENT STRUCTURE

4.1 POLICIES AND GOALS

DOD policy on hazardous wastes is to comply to the fullest extent with all Federal, state, and local laws, regulations, and standards. The military services intend to comply with the letter of the law in the same manner as other Government agencies and private industries are required to comply.

The primary mission of the military, however, remains defense preparedness, and the majority of DOD's budget and manpower is devoted to this end. Compliance with environmental regulations is considered an accepted part of every military installation's operating requirements. This situation is analogous to the civilian sector's incorporation of environmental pollution abatement measures in the overall cost of doing business. Both the military and civilian sectors have become aware of the effect of improper hazardous waste management on their personnel, the general public, and the environment.

The sound management of hazardous wastes requires more than careful disposal considerations. It requires thorough definition and characterization of the waste problem, rigorous planning, and comprehensive and effective implementation of systemwide policies and goals. The following policies have been established by DOD for managing hazardous wastes.

<u>DOD</u> (DOD, 1980b)

1. Limit the generation of hazardous waste through alternative procurement practices and operational procedures that are environmentally attractive yet fiscally competitive

2. Reuse, reclaim, or recycle resources where practical and thus conserve on total raw material usage

3. Exhaust all other actions mandated by Federal statutes or regulations before identifying the material as discardable

4. Dispose of hazardous waste in an environmentally acceptable manner according to the disposal policy established by DOD

5. Implement within DOD the hazardous waste management regulations that EPA published under Subtitle C of the Resource Conservation and Recovery Act (RCRA) or that states enact under EPA authorization

6. Consider all unused hazardous materials as not regulated under RCRA until a decision is made to discard them

7. Ensure that all used hazardous materials are safely handled, accounted for, and controlled by internal DOD documentation

These policies consider and incorporate EPA's hierarchy of desired options for managing hazardous waste, as shown below.

. EPA (EPA, 1980d)

1. Minimize the amounts generated by modifying the industrial process involved

2. Transfer the waste to another industry that can use it

3. Reprocess the waste to recover energy or materials

4. Separate hazardous from nonhazardous waste at the source and concentrate it, which reduces handling, transportation, and disposal costs

5. Incinerate the waste or subject it to treatment that makes it nonhazardous

6. Dispose of the waste in a secure disposal facility (one that is located, designed, operated, and monitored -- even after it is closed -- in a manner that protects life and the environment)

On both of these priority lists, the emphasis on hazardous waste management begins before the waste is actually produced, by reducing waste volume. This is followed by in-process alternatives (recycling and reuse, segregation and concentration, resource recovery, materials exchange, treatment and destruction) and then disposal. The general policy is to manage hazardous and toxic materials by minimizing the wastes produced. Not all waste streams can be reduced or eliminated from industrial processes, and procedures must be developed to manage wastes properly and in compliance with EPA interim standards and guidelines.

4.2 OVERALL MANAGEMENT

DOD management emphasizes a strong command system with responsibility placed on the installation commander. The headquarters and major command offices establish overall policy criteria and guidance for various activities and often provide funding, technical guidance, and research and development support. Although upper management monitors compliance actions, they do not generally get involved in the day-to-day management at the installation level. Thus, the base commander is required to comply with all pertinent regulations and, in

fact, is the official responsible for signing all environmental permit applications.

DOD, through its departments and agencies, has developed several policies and specific guidance programs to comply with current RCRA requirements. Table 4-1 describes the pertinent DOD hazardous material management policies set for the military departments and agencies. These policies are applicable to the service branches for their implementation and reflect pertinent legislation affecting DOD.

4.3 PROGRAM AREAS

DOD's hazardous waste program encompasses two areas:

- Identification, control, and cleanup of past inactive or abandoned disposal sites

- Management of hazardous waste from current and future operations

4.3.1 Management of Hazardous Waste From Past Operations: Installation Restoration Program

The Installation Restoration (IR) program was initiated by DOD in 1975. Regarding this program of managing abandoned military hazardous waste sites, George Marienthal, Deputy Assistant Secretary of Defense for Energy, Environment, and Safety, stated "that [DOD] must revisit the past with today's knowledge to reevaluate [DOD's] disposal actions" (ADPA, 1980). Like other generators of hazardous waste, the military used disposal techniques that were accepted practice at the time. Since 1975, however, DOD has taken the lead in establishing a systematic effort to deal with abandoned sites where time has proven these disposal techniques to be less than satisfactory.

The IR program is directed toward existing and potential environmental problems created by past operations at DOD facilities, such as manufacturing, waste disposal, and weapons testing practices. Defense Environmental Quality Program Policy Memorandum (DEQPPM) No. 80-6, Identification of DOD Hazardous Material Disposal Sites, describes and directs IR program implementation, as follows:

- Policy

  - Assess the migration of hazardous material contaminants from DOD installations

  - Abate contaminants that have an impact on public health or the environment

Table 4-1. Significant DOD Policies on Hazardous Waste Management

DOD Policy	Subject	Description	Effective Date
DOD Directive 6050.8	Storage and disposal of non-DOD-owned hazardous or toxic materials on DOD installations	Limits the use of DOD installations for the storage or disposal of non-DOD-owned toxic or hazardous materials.	August 24, 1981
Defense Environmental Quality Program Policy Memorandum (DEQPPM) No. 81-3	DOD hazardous material disposal	Issues DOD policies on spill residue cleanup and conforming storage.	June 15, 1981
DEQPPM No. 80-5	DOD hazardous material disposal	Issues policy and implementation guidance to military departments and Defense Logistics Agency (DLA) for environmentally acceptable hazardous materials disposal procedures.	May 13, 1980 (supersedes DEQPPM No. 79-4, December 17, 1979)
DEQPPM No. 80-6	Identification of DOD hazardous material disposal sites	Provides basis for Installation Restoration Program and guidance to assess and control the migration of environmental contamination from past disposal operations.	June 24, 1980
DEQPPM No. 80-7	DOD hazardous and solid waste management committee	Expands scope of committee by including the coordination of the DOD program for managing and disposing of hazardous waste. Committee reports to the DOD Environmental Quality Committee.	May 13, 1980
DEQPPM No. 80-8	RCRA hazardous waste management regulations	Directs military departments and DLA to implement hazardous waste management regulations under RCRA. Requires, wherever feasible, reducing, reusing, reclaiming, or recycling hazardous waste generated. Established installation commander as responsible entity for RCRA compliance for facilities and activities.	October 21, 1980
DEQPPM No. 80-9	DOD management of polychlorinated biphenyls (PCBs) and PCB items	Directs all DOD departments and agencies to comply fully with EPA regulations for the handling, storage, marking, and disposal of PCBs and PCB items.	November 10, 1980
DOD Memorandum (interim guidance)	Oil recycling and reuse policy	Provides guidance on the reclamation, recycling, and sale or procurement of lubricating oils (both crankcase and industrial).	June 4, 1979 (to be incorporated into DOD Directive 4165.60)
DOD Instruction 6050.5	Hazardous material information system	Establishes a DOD hazardous material data bank. Collection, maintenance, and dissemination of hazardous material data would assist DOD personnel in (1) developing procedures to prevent mishaps in the handling, storage, use, transportation, and disposal of hazardous materials; (2) assessing the hazard of materials encountered in DOD workplaces; and (3) developing environmentally acceptable disposal practices.	January 25, 1978

- Requirements

  - Develop an installation priority list and a schedule for evaluation

  - Conduct records searches of priority list installations

  - Conduct preliminary field surveys of selected installations

  - Report on survey results and identify further technical base development and containment or decontamination operations

Since the IR program's inception, the Army has been designated the lead DOD agency to (1) compile and refine applicable technology; (2) develop new or improved technology, criteria, or standards for the restoration program (including all chemical, biological, and radiological contamination); and (3) prepare a conceptual plan of the overall program approach, cost benefit analysis, and estimated funding requirements. Table 4-2 describes the various phases of the Army's IR program. Based on the Army's concept, the Navy and Air Force have recently adopted procedures similar to the Army's program.

The IR program will first address those DOD installations with imminent migration problems. Priorities are established for designated installations based on several factors, including the type of past and current industrial and strategic operations, the environmental sensitivity of the area, the degree of urbanization surrounding the installation, and other information learned from previous environmental surveys. It should be noted that already excessed DOD properties are not included in the program.

The IR program consists of three phases: assessment, development, and operations. The assessment phase is further divided into records search and survey phases. The records search involves a comprehensive search and review of installation and archival records, interviews with key current and retired personnel, aerial surveys, and physical site surveys. An assessment of potential contamination and migration is made, based on the acquired evidence, and is documented in a technical report with findings and recommendations. The report is reviewed by high-level command personnel of the appropriate service. Evidence supporting the presence of a contamination and migration problem with an immediate health or environmental threat at the installation will provide the basis in deciding whether the investigation should proceed into the survey phase.

Such a survey may include extensive sampling and analytical monitoring at identified potential contaminated sites to quantify the problem. The objective of the survey is to confirm whether or not a

Table 4-2. Army Installation Restoration Program (Berkowitz, 1979)

Phase	Phase Description	Remarks
1. Assessment		
a. Records Search	Historical review of official data and records relating to missions of nominated installations Identification of potential existence of contaminated land mass areas, equipment, or buildings	Elimination of noncontaminated sites.
b. Survey	Identification of possible contamination/migration by onsite physical survey and sampling (e.g., surface water and groundwater flow and migration patterns, disposal sites identification, bedrock contour mapping, ecological monitoring, laboratory analysis, etc.)	May be performed by engineer contractor.
Confirmation Decision Point → No Contamination → Publish Findings ↓ Yes Contamination ↓		
2. Development	Develop concept plan for corrective action • Quantify needs • Develop control protocol and standards • Identify geotechnical, chemical, ecological, and other requirements • Perform necessary supportive R&D	Plan for containment of potentially harmful contaminants within boundaries of affected DOD installations Three installations (Rocky Mountain Arsenal, Redstone Arsenal, and Pine Bluff Arsenal) have off-post contaminant migration.
3. Operations	Implement cost-effective cleanup measures commensurate with anticipated risks and benefits • Authorize military construction funding • Design • Construct • Operate • Certify cleanup and closure of site	Magnitude of cleanup operations uncertain at present

Information for this table also received from A. Anderson, U.S. Army Toxic and Hazardous Materials Agency, February 2, 1981.

pollution problem exists. Interim measures may be employed at this time to contain, treat, or decontaminate any migration of pollutants that may exist at the installation boundary or pose a threat to the health of installation personnel.

The second phase, development, may be required if the contamination or migration problem cannot be controlled by current state-of-the-art technology. Through a triservice coordinating committee, each service can request the U.S. Army Toxic and Hazardous Materials Agency to develop appropriate technology and standards. The agency will (1) develop proposed pollutant criteria and standards in accordance with environmental, health, and safety considerations; (2) establish appropriate sampling and analytical protocol techniques as required; and (3) develop design criteria to control, treat, or otherwise decontaminate the pollution problem in a cost-effective manner. Corrective measures involve the design, construction, and implementation of pollution abatement operations. Evaluation of and funding for these measures are conducted within each service's normal internal project and cost development procedures and the military construction authorization process for capital projects. This phase provides a concept plan that outlines the engineering, management, and financial resources required for site cleanup.

The IR program exemplifies DOD's efforts to identify, characterize, and control environmental contaminants. Although assessment, development, and operational phases continue throughout DOD, a strong and orderly program has been developed and should be closely observed by industry and Government alike. To date, approximately 1500 major and minor installations have been reviewed, with over 300 requiring further survey and analysis. Although DOD has not yet identified and surveyed all of its sites, a concerted effort is being made to resolve one of its most serious environmental problems.

The operations phase involves planning for the design, construction, and operation of remedial operations. Military construction funding requests are also initiated. Site cleanup and closure certification constitute final operations activities.

Table 4-3 presents the current IR program status for the three service branches. Because the Army has been engaged in the program for the last 6 years, it is further along in its surveys than are the Navy and Air Force. The Navy and Air Force initiated their respective IR programs in 1979. The survey results and analysis should provide useful data on the extent and condition of past DOD disposal sites. Formerly owned DOD property is not included in the IR program.

EPA is currently supporting a proposal to delegate the Corps of Engineers (COE) as the lead technical agency for the design, engineering, and construction of hazardous waste site cleanup under the Superfund program (Environment Reporter, 1981b). Under an interagency

Table 4-3. Status (as of July 1981) of the Department of Defense's Installation Restoration Program (Marienthal, 1981)

	Air Force	Army	Navy
Potential Sites	66	200	79
Record Searches			
Initiated	17	115	6
Followup Needed	Not available	40	Not available
Final Reports	4	84	0

agreement, COE would oversee the actual construction work of private bidders, and EPA would retain overall Superfund management responsibilities. COE access to experience and management expertise in the design and construction management areas were cited as two reasons for EPA's recommendation.

EPA would still investigate and select sites, develop remedial options, perform cost-effectiveness analyses, and determine overall compliance with the National Environmental Policy Act (NEPA). In addition, EPA would maintain nontechnical authority, including community relations, assurance of state matching funds, and postclosure monitoring. Under Executive Order (E.O.) 12316, DOD has the authority to manage its own facilities.

4.3.2 Management of Hazardous Wastes From Current and Future Operations

As described in Section 3, Subtitle C of RCRA requires EPA to issue major implementing regulations to define hazardous wastes and establish a cradle-to-grave management system. The RCRA management system will require considerable time and effort on the part of EPA to issue standards as well as issuing permits to operate. In addition, EPA may authorize a state to establish and operate a hazardous waste program instead of the Federal program if the state meets the standards. Civil and criminal penalties of fines and/or imprisonment are to be enforced if there is a failure to comply with the act.

All of these developments have direct implications on military operations. E.O. 12088 directs all Federal agencies to comply with

pollution control standards.* The order requires all agencies to adhere to all substantive, procedural, and other requirements as though such agencies were private institutions or persons. Compliance with RCRA as well as other Federal, state, and local environmental regulations is mandated to be an integral part of pollution abatement programs within DOD. Policies described in Table 4-1 form the basis for the service branches to implement their respective programs for compliance.

The designation of individual installation commanders as responsible for environmental compliance is necessary due to (1) the uniqueness of each facility in terms of hazardous wastes generated and the management options available and (2) the multitude of Federal, state, and local regulations imposed. To facilitate these compliance efforts, DOD has designated the Defense Property Disposal Service (DPDS) of the Defense Logistics Agency (DLA) as the DOD manager for disposal of most hazardous wastes (DOD, 1980a). The service branches and their respective installation commanders must still ensure overall compliance; however, centralized control is considered the most effective approach for handling and disposal operations. It is hoped that this centralized system will assist in areas such as ensuring better compliance with substantive and procedural regulations; better coordination with regional, state, and local authorities; and avoidance of duplication (staff, facilities, equipment, and technical experts).

It cannot be determined now how this approach is working in these areas. DPDS will implement this responsibility as part of its normal cycle of excess/surplus/waste disposal management activities (Figure 4-1). Furthermore, under DEQPPM 80-5, DPDS is responsible for hazardous waste disposal when the generating activity turns in the waste to DPDS in a properly identified, labeled, and nonleaking, safe-to-handle container. Figure 4-2 identifies various RCRA responsibilities for the services and DPDS. Table 4-4 further delineates DLA and service responsibilities. The military activities are in various stages of assuming these responsibilities and will significantly alter their methods of operation.

DPDS currently does not have all the required expertise to handle this mission (Col. Robert Hamblin, Director and Deputy Commander of DPDS, Battle Creek, Michigan, personal communication, April 21, 1981). However, DPDS does intend to have a complete headquarters and field-level staff of contract/procurement, technical, legal, operations, and other support specialty personnel to properly implement the program. Its prevalent policy is to contract the waste disposal activities to qualified private operators. A Directorate of Environmental Protection has been formed to assume most of these responsibilities.

A joint DLA-services effort to provide conforming storage facilities throughout DOD is currently underway. Initial evaluation of storage

---

* 43 FR 47707, Federal Compliance With Pollution Control Standards, October 13, 1978.

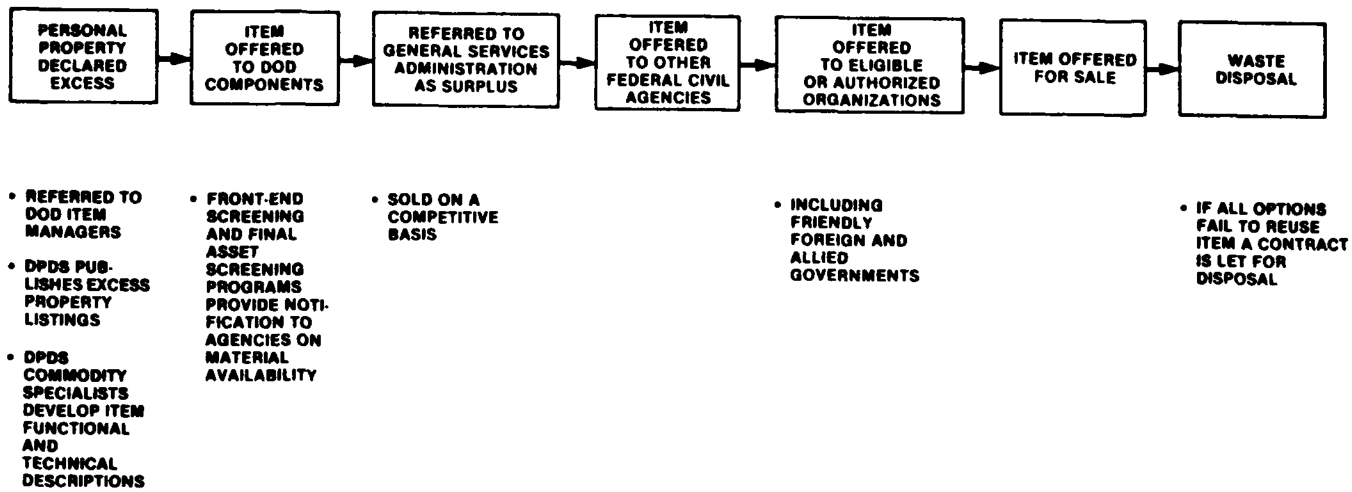


Figure 4-1. DPDS Disposal Program

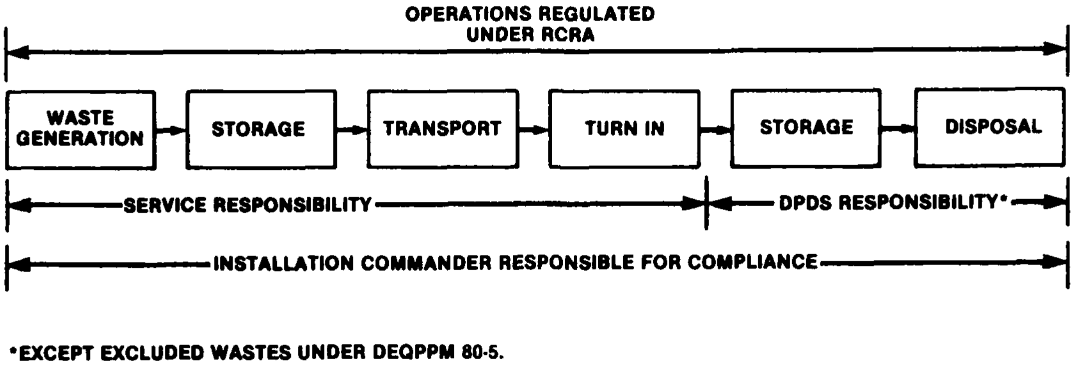


Figure 4-2. Hazardous Waste Management Responsibilities

facilities is being conducted with hazardous material/waste surveys and current requirements to achieve conforming storage. Military construction projects are being planned to begin in fiscal 1982.

Despite the large responsibility acquired by DPDS, the individual services will continue to have responsibility for the proper management of their wastes. The following hazardous waste categories are exempted under DEQPPM 80-5 and will require cradle-to-grave supervision by the DOD individual services:

- Toxicological, biological, radiological, and lethal chemical warfare materials which, by U.S. law, must be destroyed. Disposal of the byproducts of such material is the responsibility of the DOD component with assistance from DLA.

- Material that cannot be disposed of in its present form due to military regulations, e.g., consecrated religious items and cryptographic equipment.

- Municipal-type garbage, trash, and refuse resulting from residential, institutional, commercial, agricultural, and community activities, which the facility engineer or public works office routinely collect.

- Contractor-generated materials that are the contractor's responsibility for disposal under the terms of the contract.

- Sludges resulting from municipal-type wastewater treatment facilities.

Table 4-4. Military Planning and Management Responsibilities for Implementing RCRA

Joint DLA/Service Responsibilities	DLA Responsibilities	Service Responsibilities
Develop installation-wide emergency plans to furnish protection from spills, fires, explosions, or other accidents involving hazardous waste • Jointly developed by installation personnel, including fire, medical, supply, engineering, environmental, etc. • Maintain capability to implement the hazardous waste emergency plans, and be responsible for plan implementation	Establish and maintain required documentation for inspection and operational reports and other EPA requirements	Use nonhazardous, nontoxic materials whenever possible
Review waste generation activities, and designate waste accumulation points where waste can be accumulated for less than 90 days	Requisition, label, and issue approved and compatible hazardous waste containers	Where feasible, minimize quantities of hazardous waste through resource recovery, recycling, source separation, and acquisition policies
Survey and assess installation hazardous waste storage facilities and modify existing facilities or construct new approved facilities	Schedule collection of wastes from waste accumulation points to permitted facilities	Survey and evaluate current hazardous waste management practices
Implement training program for installation service and DLA personnel as required by RCRA	Provide any required repackaging or handling of hazardous materials subsequent to acceptance of accountability from the generating activity	Develop hazardous waste management and emergency contingency plans
Eliminate redundancy in organization and management system	Develop program procedures by which hazardous materials can be accepted according to DEQPPM 80-5 guidelines for physical custody and accountability criteria	Comply with Federal, state, interstate, and local requirements and standards for the generation, transportation, treatment, handling, storage, and disposal of solid and hazardous wastes • Secure necessary permits • Monitor and report compliance status
	Develop an inventory control system for types, quantities, and locations of toxic and hazardous wastes that are available for turn-in or are in storage, to avoid extended delays in the disposal process	Maintain coordination with appropriate regulatory agencies and DOD components
	Plan program budget and operate all storage facilities in support of the DLA assigned disposal mission	Discontinue "open dumping" practices
	Initiate, through normal budgeting channels, contracts or agreements for disposal technology not available in house or from the DOD components	Establish required records, manifests, and reporting systems required by Federal, state, and local regulatory agencies
	Coordinate policy and guidance with other DOD components for the disposal of hazardous waste	Notify DPDS/DLA of intent to generate hazardous wastes, including volume, type, characteristics, etc.
	Establish and maintain an analysis and information distribution capability to • Evaluate the impact and applicability of current technological advances on DOD hazardous material disposal procedures, and inform the DOD components of these developments on a continuing basis • Ensure that the DOD components are apprised, on a continuing basis, of any Federal, state, regional, and local regulations being developed to control hazardous material disposal	Transfer accountability of toxic and hazardous material/waste for which it has disposal responsibility to DLA. If permanent EPA-conforming storage is not available, the unit (service or DLA) with the most nearly conforming storage will accept physical accountability.
		Provide transportation assistance, if requested, to transport waste from accumulation points to permitted facilities
		Properly identify, package, label, and certify conformance with established criteria prior to transfer of accountability to DLA; subsequent repackaging or handling is the responsibility of DLA
		Establish custody and responsibility designations per DEQPPM 80-5 guidelines

Table 4-4. Military Planning and Management Responsibilities for Implementing RCRA (Continued)

Joint DLA/Service Responsibilities	DLA Responsibilities	Service Responsibilities
	Provide feedback to the military departments and defense agencies on the costs associated with disposal, to be used as an economic incentive to minimize waste generation Minimize environmental risks and costs associated with extended care, handling, and storage of hazardous materials by accomplishing disposal within a significantly compressed disposal cycle • Prepare environmental impact assessments or statements as required	Repackage, if necessary, hazardous and toxic wastes generated by that service and designated for disposal, to ensure package integrity during transportation and disposal operations In the event that DLA does not possess such facilities, furnish them with facilities capable of being secured (locked, fenced, etc.) on an interim basis for use as permitted storage facilities (DLA will plan for and alter or construct all required new facilities) DOD components shall plan to carry out their responsibilities through normal budgeting channels Provide all available information to DLA, as required, to complete environmental documentation, e.g., environmental impact statement associated with disposal When requested, the DOD components will assist DLA by providing information and comments on Federal, state, regional, and local regulations being developed to control hazardous material disposal, e.g., ability of particular installations to comply and impact on DOD; the DOD components will alert DLA to any local situation that could affect hazardous materials disposal Maintain and provide technical and analytical assistance, including R&D support to DLA and other DOD agencies as required to determine prudent means of management and disposal of military-unique items that are generated within DOD operations Dispose of military-specific wastes excluded from DLA's responsibilities (e.g., municipal solid wastes, manufacturing byproducts, waste treatment sludges, etc).

Adapted from DOD, 1980a; USAEDH, 1980; AFESC, 1980; NEESA, 1978.

- Sludges and residues generated as a result of industrial plant processes or operations.

- Refuse and other discarded materials that result from mining, dredging, construction, and demolition operations.

- Unique wastes and residues of a nonrecurring nature that are generated by research and development experimental programs.

EPA has listed hazardous items from nonspecific (40 CFR 261.31) and specific (40 CFR 261.32) sources as wastes immediately upon their creation; they are managed as hazardous wastes from that point. These items are turned in to the Defense Property Disposal Office (DPDO) as hazardous wastes and are manifested if transport to the DPDO for turn-in involves the use of public highways. Eight categories of the items on the 40 CFR 261.31 list are presently designated by DPDS as predetermined hazardous wastes upon receipt at the DPDO:

a. F001 -- The following spent halogenated solvents used in degreasing: tetrachloroethylene; trichloroethylene; methylene chloride; 1, 1, 1-trichloroethane; carbon tetrachloride; and chlorinated fluorocarbons.

b. F002 -- The following spent halogenated solvents: tetrachloroethylene; methylene; chloride; trichloroethylene; 1, 1, 1-trichloroethane; chlorobenzene; 1, 1, 2-trichloro-1; 2, 2-trifluoroethane; ortho-dicholorobenzene; and trichlorofluoromethane.

c. F003 -- The following spent nonhalogenated solvents: xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol.

d. F004 -- The following spent nonhalogenated solvents: cresols and cresylic acid and nitrobenzene.

e. F005 -- The following spent nonhalogenated solvents: toluene, methyl ethyl ketone, carbon disulfide, isobutanol, and pyridine.

f. F007 -- Spent cyanide plating bath solutions from electroplating operations (except for precious metals electroplating spent cyanide plating bath solutions.*)

---

* These solutions and sludges are turned in for processing under the Precious Metals Recovery Program and should be turned in as hazardous materials.

g. F009 -- Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process (except for precious metals electroplating spent stripping and cleaning bath solutions.*)

h. F015 -- Spent cyanide bath solutions from mineral metals recovery operations.

None of the items listed in 40 CFR 261.32 are to be received at the present time.

The 40 CFR 261.33(e) and 40 CFR 261.33(f) listed substances become hazardous waste only when they are discarded or are intended to be discarded. DOD/DPDS policy is that these items remain hazardous material while undergoing DPDS reutilization, transfer, donation, and sales efforts. These materials become hazardous wastes (and subject to the provisions of RCRA) only after DPDS has determined that there is no requirement or use for the material. At this point, the DPDS intent is to discard the property (possibly by incineration or landfill burial), and the property is managed as a hazardous waste. Disposal is accomplished by service contract with commercial sources in accordance with Federal procurement regulations and Federal, foreign, state, and local environmental laws and regulations.

Compliance with permit requirements is still the responsibility of the base commander, although DPDS may also be responsible as the qualified treatment, storage, and disposal (TSD) facility operator and may be required to cosign with the installation commander on permit applications.

Because each installation may be expected to maintain several TSD facilities as well as to generate waste, the actual number of RCRA permit applications will exceed the total number of installations reporting. Further, for the November 19, 1980, Part A RCRA permit applications, it has since been determined that the majority of military installations had over-reported on their permits. For example, the Air Force originally applied for 194 treatment, 309 storage, and 29 disposal permits when, after review of these applications, 95 treatment, 279 storage, and 28 disposal permits were actually required (Richard C. Kibler, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida, personal communication, August 3, 1981). EPA and appropriate state agencies will review and rule on each permit application.

---

* These solutions and sludges are turned in for processing under the Precious Metals Recovery program and should be turned in as hazardous materials.

4.4 ORGANIZATIONAL RESPONSIBILITIES

Table 4-5 lists the offices within DOD and the service branches that have hazardous waste responsibilities. This table provides a comparison of functions between branches. Organization charts depicting these offices are also presented in Appendix C to show the management relationships. The hazardous waste responsibilities of these offices are discussed in more detail below.

Department of Defense -- A small staff exists at the DOD level to manage hazardous waste affairs. This group is located in the Facilities, Environment, and Economic Adjustment Office (EF) of the Assistant Secretary for Manpower, Reserve Affairs and Logistics (MRA-L). The main hazardous waste function of this Office is to provide policy guidance to other DOD offices and the service branches and to coordinate compliance efforts. Much of the responsibility for ensuring hazardous waste compliance is placed on the service branches. The Research and Advanced Technology Office of the Under Secretary for Research and Engineering (R-E) also has responsibilities for coordinating environmental research in the hazardous waste area.

The Defense Logistics Agency, and specifically the Defense Property Disposal Service within DLA, has been given the single manager role for disposal of most military hazardous wastes. DPDS was created to serve all DOD agencies to ensure that excessed military property is disposed of according to Federal regulations. This responsibility includes evaluating salvage and resale possibilities. In its new hazardous waste role, DPDS will handle wastes from all military operations, except for the eight exempted categories described earlier. DPDS, through DLA, reports directly to the Assistant Secretary for Manpower, Reserve Affairs and Logistics.

DLA is also seeking to establish a Hazardous Materials Technical Center (HMTC) in fiscal 1982 (D. Appler, DLA, personal communication, October 7, 1981). HMTC's objective is to provide a data base, products, and services operation that will increase the productivity and the knowledge of personnel involved in the handling of hazardous materials for DLA. HMTC will acquire technical information on hazardous materials and develop and maintain a technical expertise capability to review, analyze, and synthesize the information. Potential users will be DOD components, Government agencies, and the private sector.

Air Force -- Hazardous waste policy for the Air Force originates from the Engineering and Services Office within the Deputy Chief of Staff for Logistics and Engineering (LE). This Office is also the central point in the Air Force structure for technical and construction information regarding hazardous wastes. The Air Force Engineering Services Center (AFESC) at Tyndall Air Force Base, Florida, provides

Table 4-5. Organizational Responsibilities for Military Hazardous Wastes (See Also Appendix C)

Program	Responsible Organization[a]			
	DOD	Air Force	Army	Navy
Guidance and Directives				
- Policy	MRA-L(EF)	LE	SAIL & FM	NOP-04
- Technical	b	AFESC, AFRCE	COE	NAVFAC, NEESA
Installation Restoration Program		AFESC[c]	USATHAMA	NAVFAC, NEESA
- Identification	b	AFMSC, OEHL	USATHAMA	NAVFAC, NEESA
- Engineering/ Restoration	b	AFRCE, COE	COE/Huntsville	NAVFAC
Supply, Handling, and Transportation	DLA	LOG	DARCOM	NAVMAT (NAVSUP)
Waste Storage	DLA	DLA[d]	DLA[d]	DLA[d]
Waste Treatment and Disposal	DLA[e]	DLA[e]	DLA[e]	DLA[e]
Occupational Health and Safety	MRA-L(EF)	AFSG	DASG-ZA, SAIL & FM	NOP-04
Environmental Studies	MRA-L(EF)	AFESC	USAEHA	NEESA
Training and Evaluation	MRA-L(EF)	AFESC	USATHAMA, COE	NAVFAC, NEESA
Research and Development	USATHAMA	AFESC	USATHAMA, COE, USAMBRDL	NAVFAC, NEESA

Notes:

[a] See Abbreviations (page 69) for definitions.
[b] Means no specific organization has been assigned this responsibility and/or there are no suitable organizations for this purpose.
[c] Responsibilities to be turned over to major commands.
[d] DPDS is responsible for the management and funding of all disposal contracts for which it has responsibility under DEQPPM 80-5. DPDS assumed responsibility for the bulk of DOD contracts in fiscal 1981 and arranged the phased-in assumption of the remaining existing service contracts during fiscal 1982.
[e] DLA does not contemplate any military-owned treatment or disposal systems and will contract for these services.

technical and environmental assistance, training and evaluation, and research and development support, and coordinates the IR program for the Air Force. The Air Force Regional Civil Engineers (AFRCE), located at three offices throughout the United States, coordinate interfaces with Air Force base environmental personnel and other Federal and state agencies. They also oversee Air Force construction, with the actual construction managed by the Army Corps of Engineers. Both of these groups report to the Engineering and Services Office.

The Air Force Surgeon General (AFSG) is responsible for the health-related impacts of hazardous materials, particularly worker exposure and occupational health, and reports directly to the Chief of Staff. AFSG is also responsible for onsite monitoring under Phase II of the IR program and for establishing appropriate environmental contamination standards. The Air Force Medical Services Center (AFMSC) at Brooks Air Force Base, Texas, provides policy guidance and direction concerning bioenvironmental engineering consulting and laboratory services for the Air Force. AFMSC also develops health and environmental standards as needed. The Air Force Occupational and Environmental Health Laboratory (OEHL) also acts as a pollution abatement consultant to the Air Force.

The Logistics Command (LOG), a major command reporting to the Chief of Staff, controls the acquisition, supply, and disposal of materials for the Air Force. Thus, LOG has control over much of the hazardous material used by the Air Force, and works very closely with DLA and DPDS in material procurement and disposal. LOG also operates the Aircraft Logistics Centers, where major overhauls and

Army -- The Environment, Safety and Occupational Health Office of the Assistant Secretary for Installations Logistics and Financial Management (SAIL & FM) is responsible for preparing hazardous waste policy for the Army. The Chief of Engineers is the staff manager of the Army environmental quality program, including research and development, construction, and maintenance aspects. The Surgeon General (DASG-ZA) monitors the health and welfare aspects of hazardous waste, including environmental and health effects and occupational health research. Surveys and studies are conducted by the U.S. Army Environmental Hygiene Agency (USAEHA) of the Surgeon General to support Army installation compliance efforts with environmental regulations.

The U.S. Army Materiel Development and Readiness Command (DARCOM) is the logistics command for the Army. In addition to procuring and handling much of the total Army hazardous material inventory, this Command also uses and produces hazardous materials in its unique manufacturing operations, i.e., munitions production and demilitarization. Most of DARCOM's own wastes (e.g., munitions manufacturing wastes) are outside DLA's responsibility for disposal and must be disposed of through DARCOM contracts. The U.S. Army Toxic

and Hazardous Materials Agency (USATHAMA), an organization under the command of DARCOM, has a unique role in military hazardous waste, acting as the lead organization for all DOD IR programs. Although each service maintains its own separate program, USATHAMA provides IR-related research and development for all of DOD and gives guidance to the other program managers. USATHAMA provides environmental quality research and development support to DARCOM in the munitions and propellants manufacturing area and is also the lead DOD agency for the chemical warfare agent/munitions demilitarization program. The Corps of Engineers provides overall design and construction support to environmental protection programs such as the IR program through its regional division and district organizations. The U.S. Army Medical Bioengineering Research and Development Laboratory (USAMBRDL) at Fort Detrick, Maryland, performs environmental and health effects studies for the IR program and munitions plant wastes.

Navy/Marine Corps -- Although the Navy and Marine Corps are separate organizational entities, the Marine Corps does not have a sufficient support staff to handle its limited hazardous waste matters. The Marines issue their own policy guidance, but use Navy staff (i.e., Naval Facilities Engineering Command) for technical assistance and management of their IR program.

Naval policy for hazardous wastes is provided by the Environmental Protection and Occupational Safety and Health Office of the Deputy Chief of Staff for Logistics (NOP-04). Technical assistance is provided through the Naval Facilities Engineering Command (NAVFAC) and the Naval Sea Systems Command (NAVSEA), both part of the Naval Material Command (NAVMAT). NAVFAC manages the IR program for the Navy and the Marine Corps and provides construction services through its Engineering Field Division offices (EFD). There are six EFD regions located throughout the country. The Naval Energy and Environmental Support Activity (NEESA), an organization under NAVFAC, is responsible for training and evaluation and for environmental studies of hazardous waste. Research and development for hazardous waste also falls within the responsibilities of NAVFAC. NAVSEA is responsible for providing technical assistance for ships' hazardous waste management.

The Naval Supply Systems Command (NAVSUP) is similar to DARCOM (Army) and LOG (Air Force) in providing supplies for Navy activities and is a NAVMAT subcommand. NAVSUP is particularly concerned with hazardous material storage, transportation, and disposal.

5. CONTROL TECHNOLOGY OPTIONS FOR MANAGEMENT AND DISPOSAL OF HAZARDOUS WASTES

5.1 CURRENT TECHNOLOGY

There are two categories of hazardous waste control technology: cleanup and prevention. Past management activities often used the cheapest available disposal techniques. However, the discovery of abandoned problem sites, the promulgation of new disposal regulations, and the increasing cost of disposal have spurred the need for more effective control technologies in both categories.

5.1.1 Methods for Cleaning Up Abandoned Sites

The most prevalent method of disposing of hazardous wastes has been land burial or simple dumping (on land, into waterways, or into the ocean). Although dumping of wastes into navigable waters and streams has been regulated in the last few years, improper land disposal has only recently been recognized as a potentially serious environmental problem, because environmental damage due to land discharge may not be manifested for many decades after the initial waste burial.

As shown in Figure 5-1, a number of contaminant pathways are possible due to improper land disposal of hazardous wastes. These include groundwater pollution from leachate, surface water contamination, and ambient air contamination (from volatile waste components or windborne particulate matter). Mitigative measures in the past have mostly been limited to closing contaminated wells and bringing a new water supply into the area. Some preventative and control methods have been applied, such as constructing impervious barriers, cone-of-influence wells, or other containment barriers to prevent further migration. Recent techniques have combined these measures with decontamination treatment, as is the case at the Army's Rocky Mountain Arsenal. More extensive cleanup work is anticipated at the site, including a water monitoring plan, the cleanup of contaminated drinking water supplies, the removal of liquid from an impoundment basin, and an inventory of contaminated sites and the necessary remedial measures (Looby and Shukle, 1981).

An assessment of abandoned dump site cleanup alternatives was made to determine their technical and economic feasibility (Arthur D. Little, 1976). The study assumed a contaminated land mass area of 0.5 square mile, 25 feet deep, leaching toxic materials to groundwater.

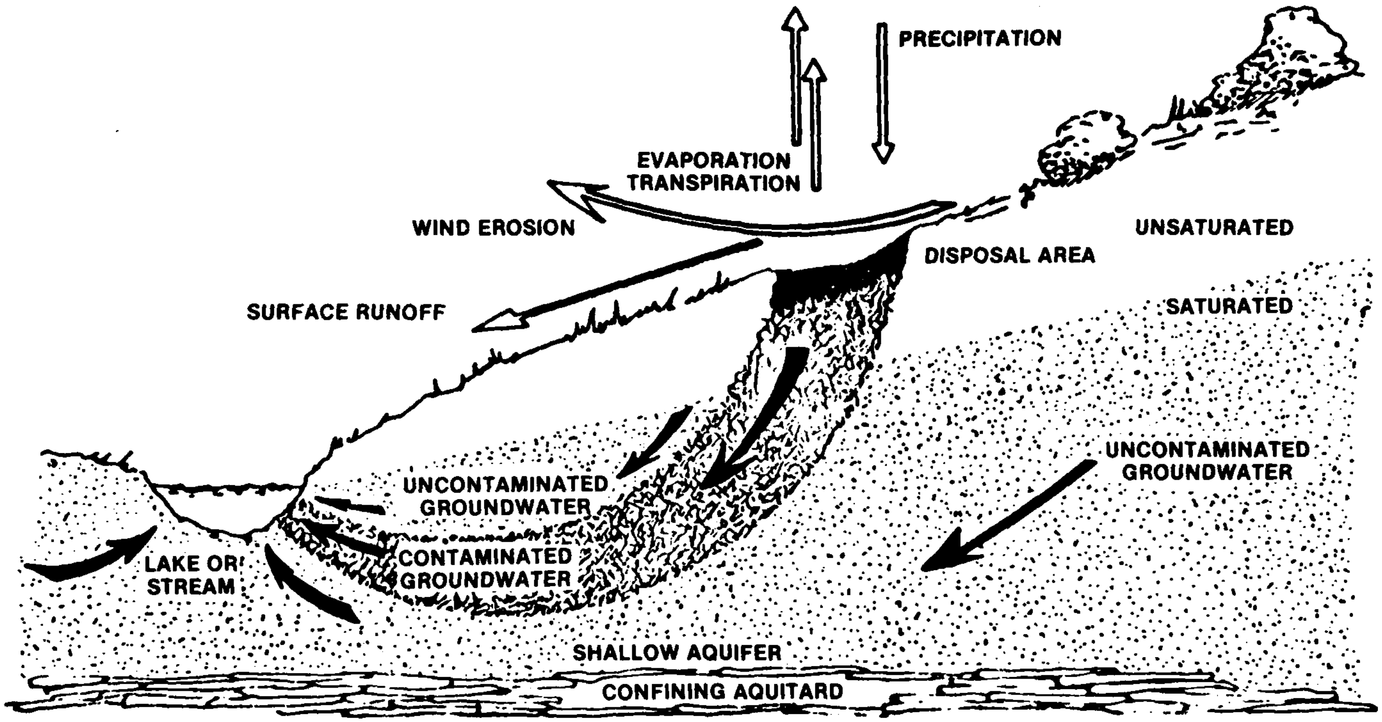


Figure 5-1. Mechanisms Covering Contaminated Transport (AAAS, 1979)

The cleanup methods are listed below and are described in Appendix D. A comparison summary of these methods is presented in Table 5-1.

- Excavation and treatment
  - Incineration and revegetation
  - Wet chemical processing
- In situ treatment
  - Soil activation
  - Vegetational uptake
  - Inoculation
- Groundwater treatment
  - Upgradient diversion
  - Downgradient collection and treatment

All of these remedial cleanup measures are very costly. This is true for the initial financing and managing of the cleanup operation as well as for the long-term maintenance and monitoring program. To date, very few of the methods have been applied and their effectiveness determined. It is hoped that as more data become available, both from the civilian (Superfund) and military (Installation Restoration Programs) sectors, a better determination can be made as to the potential overall effectiveness of these measures.

5.1.2 Methods for Preventing Hazardous Waste Contamination

Neither the Resource Conservation and Recovery Act (RCRA) nor the proposed hazardous waste regulations mandate the use of particular technologies for treatment and disposal. Whether the technology selected is incineration, landfill, basin or surface impoundment, or chemical/physical/biological treatment, the strategy must be in accordance with facility requirements under Section 3004 of RCRA.

The incineration of combustible organic wastes, fixation technologies, and the secure chemical landfill of dewatered inorganic or mixed organic/inorganic wastes are often mentioned as potential techniques for compliance, given the current knowledge of hazardous waste properties. Other environmentally sound and less costly technologies could be selected if the uncertainties in the available data, such as waste properties, were better known. For example, some of the organic solvent (both chlorinated and nonchlorinated) wastes may not be combustible. Some of these wastes might be recoverable for recycling within the generating installation or may be transferable as generated and reused elsewhere.

Table 5-1. Summary of Treatment Methods Examined[a] (AAAS, 1978)

Decontamination Method	Project Time (yr)	Capital Investment ($)	Annual Operating Costs ($/yr)	R&D Time Prior to Implementation (yr)	Chance of Success
Incineration and Revegetation	15	10,000,000	4,500,000	1-2	Very high for organics[b]
Wet Chemical Processing	15	10,000,000-25,000,000	>3,500,000	3-5	Very high in principle[c]
Soil Activation	5-20	-	1,400,000[d]	2-4	Moderate[e]
Vegetational Uptake	60	-	60,000[f]	3-5	Low
Inoculation	Unknown	-	Greater than soil activation	>10	Very low
Upgradient Ground and Surface Water Diversion	Infinite	1,200,000-2,200,000	130,000-230,000	< 2	High for containment; zero for land decontamination
Downgradient Ground and Surface Water Collection and Treatment	>50	5,900,000-9,700,000	~1,000,000	2-3	High, but very slow

Notes:

[a] For a contaminated land area of 0.5 square mile, 25 feet deep.
[b] Heavy metals may require separate treatment.
[c] Specific chemical steps require further development.
[d] Costs of a single treatment, which might suffice.
[e] No really hard data are available.
[f] Exclusive of disposal of harvest.

The very high costs associated with technologies such as incineration and secure chemical landfill provide the greatest incentive to seek other treatment and disposal technologies. These alternative technologies would be in accordance with EPA and DOD policies (Section 4) and include processing changes to reduce waste quantity or alter the character of the wastes generated, technologies to recover and reuse materials or energy, and technologies to convert hazardous wastes to nonhazardous materials. There is currently a wide cost variation both within a specific method and among the various method categories and also according to type and volume of waste handled. The relative costs per metric ton of waste for alternative treatment and disposal options are listed below (EPA, 1980d).

- Secure chemical landfill -- \$50-\$400
- Incineration (land based) -- \$75-\$2000
- Land treatment -- \$2-\$25
- Chemical fixation -- \$5-\$500
- Surface impoundment -- \$14-\$180
- Physical, chemical, biological treatment -- variable

Table 5-2 lists the various generic technologies available for both military and civilian applications and their status. Appendix D further describes and assesses many of these options. None of the technologies can be 100-percent safe, either from an environmental or public health standpoint. However, these technologies can be made reasonably safe, provided that effective control and enforcement procedures are used. In addition, the use of any of these technologies should be thoroughly analyzed and evaluated at specific locations.

5.2 R&D PROGRAMS AND TECHNOLOGY TRANSFER

Compliance with RCRA and Superfund regulations will necessitate further technological development in the cleanup and prevention programs. Table 5-3 identifies some of these areas for the military. The initial needs will be to determine the nature and extent of the problem in these two areas. Future R&D will seek effective management systems, control technology, and remedial action and emergency response capability.

The military offices contacted indicated that any current or future hazardous waste R&D activities must present a problem that is unique to the military or that greatly affects the military. Although the Army and EPA have recently agreed to a cooperative R&D program for pollution abatement technology development (Marienthal, 1981), the military will rely mainly on nonmilitary R&D efforts for technological solutions to military hazardous waste problems.

Proper waste management at military installations will require the development of a diverse array of technological options. Accordingly, R&D efforts should be directed in the following areas:

- Cleanup
  - Fires, explosions, spills, or other sudden releases
  - Human, animal, or food chain exposure to acutely toxic substances
  - Contamination of a drinking water supply
  - Adverse impact on long-term isolation

Table 5-2. Suitability Status of Various Hazardous Waste Technologies

Technology Principle	Overall Appraisal of Suitability	Advantages	Disadvantages
• Process Modification or Material Substitution	Very acceptable, in terms of preventing waste generation at the source.	• Reduces or eliminates the need for back-end pollution control • May provide a more efficient system	• May not be feasible or economical in certain cases • Requires case-by-case assessment
• Recycling Types: - POL - Solvent - Inorganic chemical - Container	Very acceptable from standpoint of being socially acceptable and utilizing sound scientific and economic criteria.	• Conserves a nonrenewable resource • Decreases environmental pollution caused by improper disposal, e.g., spills • Reduces waste amount to be incinerated or landfilled	• May not be economical, in certain cases • May require special handling procedures, e.g., for heavy metal containing sludges • Risk of air emissions and wastewater discharges
• Detoxification Treatment Physical Method Examples: - Precipitation, flocculation, and sedimentation - Filtration, ultrafiltration - Evaporation - Distillation - Carbon adsorption - Ion exchange - Reverse osmosis Chemical Method Examples: - Hydrolysis - Oxidation and reduction reactions - Solvent extraction - Ozonation - Blending and neutralization	Acceptable, provided material handled properly after treatment, e.g., when ultimately disposing of treatment residue. Accurate records of substance and placement required.	• Can reduce waste volume • Can remove hazardous constituents • Many are reasonably economical • Can be built for any scale	• Some methods suitable only in dry areas • Some methods concentrate toxic components and are not detoxification methods • May require extensive pretreatment • Some methods have high capital and operating costs
Biological Treatment Examples: - Activated sludge - Trickling filter - Aerated lagoon - Stabilization - Anaerobic digestion - Land treatment - Compost	Acceptable, used for many years for some materials. Necessary to ensure that effluents to surface waters attains acceptable quality levels.	• Does not require heat or pressure (in most cases) • Not usually labor intensive • "Natural" process	• May require larger land areas • Handles only biodegradable materials • May produce odors

Table 5-2. Suitability Status of Various Hazardous Waste Technologies (Continued)

Technology Principle	Overall Appraisal of Suitability	Advantages	Disadvantages
• Incineration Examples: - Rotary kiln - Liquid waste incinerator - Multiple chamber and traveling grate - Multiple hearth - Fluidized beds - Molten salt - Plasma arc torch - Calcination	Acceptable for certain materials, such as outdated pesticides and chemicals, provided proper safeguards employed.	• Can destroy most organic materials • Can be used for calcination in some cases • May be only method for certain materials	• Requires extensive effluent cleaning process • Potential accidents are expensive and threat to workers and surrounding area • Thermal energy intensive • Not suitable for many metal-containing organics and inorganic solutions in water • Expensive to operate
• Solidification Examples: - Silicate-based and cement-based - Lime-based - Thermoplastic - Organic polymer - Encapsulation	Sound method for disposing of inorganic materials, e.g., heavy metals. Long-term experience required on stability of material treated.	• "Detoxifies" by fixing many difficult wastes, e.g., heavy metals, by virtually eliminating leaching • Extensive short-term experience available in this new field	• May not detoxify all substances • No long-term experience on resistance to leaching • Requires secure landfill
• Deep-Well Injection	Suitable method for certain wastes with appropriate geologic location (>2000 feet, layers of impermeable rock separating material from groundwater, minimal earthquake activity, etc.)	• Accepts a variety of liquids • Economical to operate • Secure storage if properly built and operated	• Only accepts liquids • Suitable locations may be limited • Does not detoxify wastes
• Secure Landfill	Unacceptable for toxic or unstabilized hazardous material.	• Economical to operate • Relatively good depository for properly treated waste	• Not suitable for untreated hazardous materials
• Long-Term Storage	Suitable only if material cannot be adequately treated or for temporary period until recycling or other technologies are feasible. Such facilities will always be necessary.	• Wastes are recoverable • Provide temporary storage for materials for which there is at present no acceptable disposal or recovery method	• Potential for accidents high, e.g., fires or sabotage • Discourages development of alternative technologies

Table 5-3. Common Research and Development Requirements

Area	Requirement	Description
Prevention (RCRA Compliance)	Hazardous waste definition and inventory	Need to determine waste definition procedures consistent with RCRA and to develop appropriate technology options for handling and disposal.
	Degree of hazardous assessment	Required to ascertain the relative toxicity and threat of various waste streams to health and the environment.
	New technology development	Treatment and disposal options are urgently needed for broad classes of wastes. Higher disposal costs will provide a strong incentive to develop techniques that are effective and economically feasible. Technology should also be developed for small-quantity waste generators such as small military installations, businesses, laboratories, etc. In addition, alternatives should be developed for existing surface impoundments not in compliance with proposed RCRA regulations. Potential R&D areas include process activity changes and modifications in the design or operation of wastewater treatment systems.
Cleanup (Abandoned Site Problem)	Former waste disposal site inventory	The military is in the process of inventorying its installations through the Installation Restoration Programs. However, due to the scarcity of historical records, a thorough inventory will be difficult to develop.
	Risk analysis	With the numerous but unknown number of abandoned sites, an approach is needed to systematically and quantitatively set priorities.
	Mitigative remedial measures	Further development and testing of a wide range of technological options is required so that solutions can be selected that are commensurate in cost and effectiveness with the nature of the identified problems.

- Prevention
  - Minimizing quantities of material requiring disposal by procurement or process changes
  - Maximizing the recovery and recycling of resources
  - Developing biological, chemical, and physical methods for detoxification and volume reduction after wastes are generated

Future work in these areas will generate much knowledge that can be transferred between the civilian and military communities. To facilitate this information transfer and avoid duplication in R&D programs, more areas of common R&D efforts need to be identified. Past joint hazardous waste study areas have included pollution abatement from munitions manufacturing and demilitarization of obsolete ordnance.

The continuation and expansion of joint R&D efforts are necessary because (1) the already wide range of substances that constitute the hazardous waste stream creates difficult problems for a management system, (2) the continuing development and production of new substances mean a release of new contaminants, and (3) the constant improvement of techniques and detection levels of trace substances means that new waste control standards will be continually developed. In the long run, DOD research capability should be established to

- Assist in setting up testing facilities from the earliest design stages
- Cooperate with industry in solving specific manufacturing problems that lead to unnecessary waste production
- Stay abreast of industrial development to be able to cope with an increasingly large and complex hazardous waste production
- Actively participate in the development of new techniques, products, and processes for hazardous waste management

The Army and EPA have recently formally agreed to coordinate their research and development programs and allow EPA to conduct tests and demonstrations of hazardous waste control technology at Army installations. It is hoped that this cooperative effort will prevent duplication in R&D programs and promote joint research efforts.

6. SUMMARY FINDINGS AND ANALYSIS

The basic purposes of this study were to identify and examine the scope and status of military hazardous waste management activities and to assess the management and technical alternatives for disposal and cleanup. To respond to these broad management and scientific questions, the study was designed to focus on

- The magnitude and scope of the military hazardous waste problem
- Management structures to deal with control, prevention, and cleanup
- Compliance status with applicable environmental regulations
- Identification of future considerations and needs

The summary has been classified into groups of related subjects: (1) general findings, (2) policy and regulations, (3) management and operations, (4) control technology R&D, and (5) future considerations. The findings and conclusions that follow represent the project team's best judgment after a review of pertinent literature and discussion with DOD and EPA officials engaged in hazardous waste management activities. Recommendations, where appropriate, were developed to assist the DOD planning, programming, and decisionmaking system.

The project team took the position that public safety is a major consideration at all stages of project development. Hence, any management system structure or control technology proposed should not constitute a threat to human health or the environment. It is evident that the military as a whole is taking positive steps to properly control and manage its hazardous wastes.

Two overall observations emerged from the study. The first is the agreement among DOD officials that, although a management system for safely handling and controlling military hazardous wastes does exist, it must be further strengthened to meet the challenges of the Resource Conservation and Recovery Act (RCRA), Superfund, and other hazardous waste regulations. This is based on the realization that an increased buildup of defense activity will cause substantial changes in the nature of the military's industrial base and a growth in the volume and potential hazard of wastes generated. The second observation is the high public uncertainty concerning the degree and extent of hazard posed by these wastes and the reliability of environmental control

methods. The fate of military installations' maintaining good-neighbor relationships with local governments and surrounding communities may depend on how well each installation manages its own waste stream.

6.1 GENERAL FINDINGS

DOD Is Required To Comply With All Federal, State, and Local Environmental Regulations

As a Federal agency, DOD is required to be in compliance with environmental regulations, just like any other private concern. This mandate is a primary factor in all military hazardous waste management activities.

The Military Is at an Early Stage of Gathering Data on the Quantity and Characteristics of Military Hazardous Materials Procured and Wastes Generated

The formulation of an effective strategy for managing hazardous waste requires an estimate of the volume and type of waste requiring treatment and disposal. A hazardous waste inventory would assist in (1) determining what areas require improved management and [illegible] design and location of control technology facilities.

Past inventories provide only an incomplete and fragmented picture of hazardous waste generation, rather than accurate data for the design of a waste management system. As the installations report more reliable inventories to EPA and maintain accurate manifest records, the information can be used to develop a more effective waste management system. The Defense Property Disposal Service (DPDS) has initiated a hazardous material/waste survey among DOD installations to determine the nature and magnitude of the military hazardous waste stream.

Recommendation 1: The military services should develop and maintain a comprehensive inventory system to characterize their respective hazardous waste streams. Data submitted as part of RCRA and Superfund notifications can form the initial basis of the inventory but are somewhat incomplete. A consistent systematic approach of inventorying should be developed for obtaining an accurate classification and tracking of waste streams.

The Identification of Hazardous Wastes and Associated Problems, Particularly at the Installation Level, Is Considered a Major Problem Among the DOD Components

Despite the various DOD policies and EPA test protocols, hazardous waste lists, and emission standards, there remains some uncertainty at the installation level over the designation and handling of hazardous

wastes. With the over 50,000 separate hazardous material line items procured by DOD, it becomes increasingly difficult for installation personnel to wrestle with the characteristics of materials, analytical tests, the advance of technology and testing procedures, and the continual stream of new synthetic compounds. Installation personnel are counted on to recognize, handle, properly package, and turn in these wastes to DPDS or the appropriate disposer. Instructions for these procedures are often not sufficient or clear to installation personnel.

Another difficulty in complying with policy directives and regulations is the varying levels of environmental engineering and other technical expertise among installations. Larger installations may have a higher level of environmental engineering capability than smaller installations where the environmental personnel may not be engineering oriented. Reporting and overall regulatory compliance requirements, in such instances, could vary considerably depending on the interpretation of the broad policy guidance by technical personnel.

Recommendation 2: DOD should further develop the following areas:

- Provide a definitive set of criteria for hazardous waste designation, to ensure proper definition and identification of military hazardous wastes
- Consolidate current hazardous material information sources, for example, the Hazardous Materials Information System (Defense Logistics Agency (DLA)), Consolidated Hazardous Items List (Navy), and Industrial Health Hazards Inventory (Army)
- Provide central or regional technical expertise to assist base personnel in areas such as permit application and compliance, hazardous materials storage, hazardous waste reporting, waste recycling, waste generation reduction practices, spill prevention, and emergency response services
- Establish direct communication procedures between installation/major command personnel and DPDS officials to discuss and rectify specific hazardous waste definition or handling problems
- Develop training support programs for base personnel involved in the handling and management of hazardous materials

One of the Most Appropriate Solutions to the Hazardous Waste Disposal Problem Is Not To Generate Hazardous Wastes in the First Place

Through process changes, it may be possible for military activities to reduce or eliminate the production of some hazardous wastes.

Methods include a reduction in the hazardous materials used in operations, the substitution of less hazardous materials, and better quality control and techniques to reduce hazardous wastes requiring disposal. The less hazardous waste to be disposed of, the less threat to public health and risk of environmental damage.

The use of these methods may not always eliminate the waste problem, and additional abatement alternatives may have to be applied. However, waste generation control can greatly alleviate the total waste volume and degree of hazard in many military operations. For example, the Army's munitions manufacturing modernization program (ADPA, 1976) is developing several manufacturing process changes incorporating recycling, wastewater treatment, and other pollution controls.

Recommendation 3: Hazardous waste source generation control should be incorporated as an integral part of the overall military hazardous waste management program. Installation activities should be examined by base and technical support personnel to determine feasible source reduction options, such as waste separation, recycling, and reuse. Incentives to employ these options will be the development of a hazardous waste management program, stringent regulations, and the cost of hazardous waste treatment.

The Costs for Handling and Disposal of Military Hazardous Wastes Will Become an Increasing Economic Concern as Regulations Are Promulgated

The hazardous waste disposal costs associated with military operations will necessitate an increased emphasis in several phases of military system procurement, including material and product acquisitions, manufacturing, maintenance, and refurbishing operations. Economic analyses cannot be limited to research and development, acquisition, and operation and maintenance costs but should include, in the future, the projected costs and benefits of hazardous waste management. For example, the material acquisition system should include the costs of handling and disposing of any hazardous material safely and analyzing any hazardous waste salability and market research, recycling, or material substitution potential.

6.2 POLICY AND REGULATIONS

RCRA Regulations Will Limit the Options for Disposal and Increase Administrative Costs

The impact of RCRA represents significant changes in the way DOD components use and dispose of hazardous materials. The burden will be especially heavy on installation activities using large quantities and many types of hazardous materials.

The current option to landfill much of these wastes may be limited in terms of available capacity and costs, or may be prohibited in certain regions. The administrative costs of tracking the handling, storage, and disposal of hazardous waste is another concern for the military, particularly as more states assume primacy in managing RCRA compliance.

In other areas of military activities, current acceptable options may be severely limited in the near future. For example, the open burning/detonation of unstable explosive materials may not be acceptable to EPA under future RCRA regulations; however, there are presently limited alternative technologies for the vast majority of the ordnance waste generated.

Difficulty in siting treatment, storage, and disposal (TSD) facilities is one of the primary reasons that both availability and cost of waste disposal will be under question in the near future. Efforts to ensure proper operation of and controls for such facilities may not be sufficient to allay public concerns and sentiment. The use of disposal facilities providing services on a regional or areawide basis as an alternative to individual military or private onsite facilities may result in cost and environmental advantages and reduced public opposition. However, regional disposal options are in the concept stage and have not been adapted on a broader national basis.

Recommendation 4: DOD should examine potential alternatives to this problem, including the following:

- Reduce the volume of DOD hazardous waste
- Recycle or reuse DOD hazardous waste
- Participate in area or regionwide TSD systems
- Construct DOD facilities to treat, store, and dispose of hazardous waste onsite wherever use of commercial facilities are inappropriate

The feasibility of these alternatives must be determined at the installation or regional level. Close working liaison with regulatory agencies is also a vital factor in evaluating alternatives.

Full Promulgation and Implementation of RCRA Regulations by EPA Are Expected To Require Another 5 to 10 Years

The current hazardous waste regulations are voluminous and complex. However, promulgation under RCRA is far from complete, and EPA estimates that it may take several years. In addition, the development of the EPA data base and the analysis necessary to resolve the myriad of complex technical issues raised by promulgated standards will require additional time and resources.

Given such a situation, DOD, as well as other public and private organizations, is placed in a reactionary rather than an anticipatory mode. The establishment and management of military hazardous waste programs must remain flexible in order to respond to these ever-evolving regulations.

Recommendation 5: DOD should keep abreast of the latest developments from EPA and appropriate state agencies concerning military regulatory compliance requirements. The military services, through their respective commands and engineering support offices, must also ensure that this information is transmitted to the individual installations. Regulations having an effect on DOD should not merely be transmitted but should be accompanied by appropriate policy and technical guidance. Efforts by DLA and the services to gather and assess current data represent a progressive step. There remains a need to coordinate these efforts to ensure efficient transmittal of the information to installation personnel.

6.3 MANAGEMENT AND OPERATIONS

DOD Policy on Hazardous Waste Management Has Been Developed; However, a Clearly Articulated Plan of Action To Guide Program Implementation Is Required

In complying with regulations promulgated by RCRA and other legislation, DOD was faced with a large workload and a relatively small staff. DOD is currently in the process of simultaneously staffing and organizing some of its offices commensurate with this added responsibility.

A course of action for DOD hazardous waste management program implementation has been initiated; however, an implementation plan has not been developed. The implementation of Defense Environmental Quality Program Policy Memorandum (DEQPPM) 80-5 (under the supervision of the joint DOD DEQPPM 80-5 implementation task group) represents a viable approach in which DOD can effectively manage its hazardous waste stream. Furthermore, in light of RCRA deadlines and normal hiring and procurement lead times, it is evident that delay in developing a basic organizational framework and implementation approach can only serve to delay full compliance with the act.

Recommendation 6: Efforts of the 80-5 implementation task group would be improved with the development of a long-term operating plan to guide DOD program managers in carrying out hazardous waste management responsibilities. This plan would describe the development of a comprehensive program strategy and contain explicit requirements, in terms of needs, methods, schedules, and resources, for the orderly implementation of the plan by all DOD components.

DOD guidance has included a zero-based budget process, Office of Management and Budget submissions, management-by-objectives operating year plans, and DOD environmental quality policy

memoranda. These general objectives give a sense of what the thrust and tone of the program should be. It is extremely important, whatever the basic approach and plan taken by DOD in complying with hazardous waste regulations, that it is clearly understood by all management levels. Without a clear policy implementation plan and specified requirements, DOD personnel affected by the regulations cannot get a clear view of their priorities, goals, or role.

Hazardous Waste Management Is an Integral Part of Military Environmental Protection Programs, but Resource Limitations May Hinder Compliance Efforts

Environmental protection programs, including hazardous waste management, must compete for resources with the primary military mission at each installation. Although it can be argued that proper environmental protection practices assist in supporting an installation's mission and safeguarding military and civilian personnel, limited resources and competing budget expenditures make it somewhat difficult for DOD facilities to develop effective and comprehensive environmental programs. However, the efforts observed to date indicate that significant progress has been made.

The Installation Commander Has Overall Responsibility For Complying With All Hazardous Waste Regulations

The installation commander is responsible for submitting all hazardous waste permit applications and ensuring the installation's compliance. In addition, the commander must furnish any reports required by EPA or the state. Although the implementation of an installation hazardous waste management program involves many activities including supporting property disposal and tenant activities, the installation commander is responsible for ensuring that every base activity is in compliance.

Recommendation 7: The installation commander should be given adequate support both from the command level and from pertinent base personnel in order to comply. A centralized or regionalized system should be available to provide (1) assistance in dealing with regulatory agencies; (2) periodic onsite staff assistance, consultation, and review of pollution abatement operations; and (3) immediate assistance for emergency or day-to-day operations.

The Management System for Military Hazardous Waste Is Based on a Shared Responsibility Among the Various DOD Components

Despite the decision to establish DLA as DOD's single manager for hazardous waste disposal, the military services still have responsibilities

to safely manage their hazardous wastes. For example, storage will be by the military component or Defense Property Disposal Office (DPDO) that has the storage most nearly conforming to EPA criteria until DLA alters or constructs facilities that will allow the DPDO to assume physical custody. Even at that time, the services must manage their waste until turn-in to DPDS, and, for the exempted wastes under DEQPPM No. 80-5, the services are solely responsible for the entire cradle-to-grave management. Hence, although centralized contract disposal will be under a single manager, central management and responsibility does not presently characterize the overall DOD hazardous waste management system.

Recommendation 8: During the interim period in implementing DEQPPM No. 80-5, progress should continue to be monitored by the implementation task group consisting of representatives of the various military components. Representatives should maintain close communication with their respective components. The establishment of more efficient management procedures and the resolution of potential conflicts are areas in which the group should be involved. The group should report semiannually on the progress and problem areas to the Office of the Secretary for Defense (Assistant Secretary for Manpower, Reserve Affairs and Logistics).

The Treatment, Storage, and Disposal of Hazardous Waste by Private Contract Is a Common and Preferred Alternative for DOD

DOD prefers contract removal of hazardous wastes from DOD installations in the majority of cases, especially if it avoids construction and operation of waste facilities on the installation. Onsite storage requirements must be met if the waste is not removed within 90 days of its generation. Offsite removal by a private contractor for ultimate disposal does not imply that DOD is released from all liability resulting from the improper handling of such wastes. Predisposal storage facilities will be constructed and operated by the DPDO.

Recommendation 9: DOD can minimize its liability for offsite hazardous waste treatment, storage, and disposal by encouraging generators to keep careful records and perform all waste analyses, use proper manifests, use only permitted TSD facilities and transporters who have EPA identification numbers, and periodically track and audit their transporters and offsite TSD facilities.

Technical Expertise To Implement DOD and Service Directives Is Not Always Available at the Installation Level

The implementation of policy guidance requires some degree of technical expertise. Where one installation may have a highly competent staff of environmental engineers, another may have environmental

personnel who are not engineering oriented, or who find it more difficult to identify problems or define or design site-specific remedial measures. In these latter instances, policy directives may be improperly implemented or even unrecognized.

Recommendation 10: Technical guidance and assistance should be made available at the regional or command structure levels in pollution abatement direction. This guidance would be available to assist installations in providing high-quality technical assistance when needed, interfacing with Federal and state regulatory agencies, and monitoring permit compliance status. The groups that handle such assistance include the Navy Energy and Environmental Support Activity, the Army Environmental Hygiene Agency, and the Air Force Engineering Services Center and Occupational and Environmental Health Laboratory. These efforts should be expanded to assist installations in identifying problem areas as well as developing solutions.

The Installation Restoration (IR) Program Is a Systematic Effort To Identify Inactive or Abandoned DOD Hazardous Waste Sites, Accidental Spills, and Other Detrimental Environmental Practices; To Define the Nature of the Problems; and To Institute Corrective or Preventive Measures

The IR program was begun in the mid-1970s, before the public began to express concern. Although the program has not been well publicized, the knowledge gained from the experience to date could provide substantial guidance for national and state efforts.

The IR program surveys and information-gathering work are still in progress. It is clear from available information, however, that some remedial work will be required for some installations. The magnitude and cost of this control and prevention phase are unknown at present. Much of the uncertainty can be attributed to state-of-the-art limits, because the cleanup of hazardous waste sites presents new and unique challenges for which a strong scientific data base and viable technology options are simply not available at this time. For example, DOD needs to know more about (1) the health and environmental effects, especially chronic effects, caused by hazardous waste contamination; (2) screening samples of materials from sites to determine whether they are hazardous; and (3) the transport and fate of hazardous wastes as they migrate from original disposal sites.

The identification of past disposal sites on excessed DOD properties and subsequent remedial cleanup action may be future activities under the IR program. Full responsibility has been given to DOD under Superfund for any problems that may arise at both its present and formerly owned properties.

Recommendation 11: Efforts to identify and assess past abandoned sites formerly owned by DOD components should continue on a case-by-case basis. Where appropriate, DOD should provide a search of past real estate property holdings and activities and also technical expertise. Liability and cleanup responsibilities may have to be decided in the courts.

6.4 CONTROL TECHNOLOGY RESEARCH AND DEVELOPMENT

RCRA and Superfund Compliance Will Require Further Technological Development

DOD hazardous waste R&D activities are directed to application areas unique to the military. To a large extent, DOD will use the results of other Federal and private sector research for solving generic hazardous waste problems. In areas of mutual interest, EPA and DOD components can initiate joint R&D programs to share common knowledge and areas of expertise.

Recommendation 12: DOD should continue to initiate, on its own and jointly with EPA and other Government agencies and private groups, R&D efforts in the area of hazardous waste pollution abatement. Research priorities need to be identified and developed among the service branches and coordinated with DOD management.

6.5 FUTURE CONSIDERATIONS

The two most important items that will shape the development of DOD's hazardous waste management program in the future are (1) the complexity and extent of regulations and (2) treatment and disposal costs. To date, EPA's regulations on hazardous waste have been stringent and have caused serious reevaluation of existing TSD options for hazardous wastes. It is expected that additional regulations from EPA on this subject will be equally stringent and extensive. Treatment and disposal costs have risen as a result of these regulations and are projected to rise even more sharply in the future as additional and more detailed regulations are issued.

Tighter regulations and higher treatment and disposal costs, coupled with increased public concerns, should result in the following future trends within DOD's hazardous waste management program:

- The RCRA manifest system will require ever-increasing administrative attention to provide accurate accounting and reporting of waste disposition. To ease this administrative burden, DOD will more vigorously investigate the viability of substituting nonhazardous materials for hazardous materials in all its operations.

- State primacy in administering hazardous waste programs may increase the variability of regulations imposed on DOD facilities, requiring stronger liaison and coordination with local and state regulatory agencies.

- The data handling and tracking requirements of hazardous waste regulations will require DOD to develop extensive data management capabilities. Efficient data analysis systems will also be needed to evaluate compliance and technology alternatives.

- The military will have to provide comprehensive training programs for its field operations personnel. Much of the training will be of a highly specialized nature. It can be assumed that the many public and private hazardous waste programs will compete for highly trained personnel.

- Significant cost increases for landfilling, incineration, and other hazardous waste TSD methods will cause DOD to closely examine its waste generation patterns. Considerable emphasis must be placed on waste volume reductions, recycling, and energy recovery from hazardous waste streams.

- Life cycle cost analysis can be an effective aid in hazardous waste management. However, comparison of alternative management options will be difficult because the opportunity costs must be determined over the full life of the project or process.

- Delegation to DOD of monitoring and on-scene coordinating responsibilities under Superfund may greatly expand activities in this area. This self-enforcement of sites at DOD's own facilities would incorporate the concept of off-post migration control.

- R&D will be needed to evaluate alternative TSD technologies for DOD hazardous wastes items that are not DLA's responsibility.

REFERENCES

AAAS, 1979, "Scientific and Technical Aspects of Hazardous Waste Management," American Association for the Advancement of Science, report from a workshop considering problems identified by the Intergovernmental Science, Engineering, and Technology Advisory Panel, College Park, Maryland, July 11-13, 1979.

ADPA, 1976, "State-of-the-Art: Military Explosives and Propellants Production Industry," Volumes I-III, American Defense Preparedness Association, prepared for EPA Industrial Environmental Research Laboratory, PB-265-385, October 1976.

__________, 1980, Proceedings of the 11th Annual Environmental Systems Symposium, American Defense Preparedness Association, Arlington, Virginia, November 19-20, 1980.

AFESC, 1980, "Concept Paper on DLA Management of Hazardous Waste on Air Force Installations in Accordance With the Resource Conservation and Recovery Act (RCRA)," R.C. Kibler, Air Force Engineering Services Center, Tyndall Air Force Base, Florida, September 22, 1980.

Arthur D. Little, 1976, "State-of-the-Art Survey of Land Reclamation," prepared for U.S. Army, Edgewood Arsenal, Aberdeen Proving Grounds, Maryland, 1976.

Berkowitz, J., 1979, "Technologies for Handling Hazardous Wastes," presented at the Workshop on Scientific and Technical Aspects of Hazardous Waste Management, College Park, Maryland, American Association for the Advancement of Science, July 11-13, 1979.

Congress, 1979, "Hazardous Waste Disposal Report," Subcommittee on Oversight and Investigations of the House Committee on Interstate and Foreign Commerce, Government Printing Office, 1979.

__________, 1981, Testimony Before the Committee on Environment and Public Works, Subcommittee on Environmental Pollution Hearing on Implementation of the Superfund Legislation, P.L. 96-510, Comprehensive Environmental Response Compensation and Liability Act of 1980, Dirksen Senate Office Building, July 20, 1981.

DOD, 1981, "Defense/81 - Special Almanac Issue," American Forces Information Service, Arlington, Virginia, September 1981.

__________, 1980a, "DOD Hazardous Material Disposal Policy," DEQFPM No. 80-5, May 13, 1980.

REFERENCES (Continued)

__________, 1980b, "Defense Environmental Quality Program Policy Memorandum: RCRA Hazardous Waste Management Regulations," DEQPPM No. 80-8, October 21, 1980.

Environment Reporter, 1981a, "Defense Department Cleaning Up Its Dumpsites, States Say," Bureau of National Affairs, July 24, 1981, p. 403.

__________, 1981b, "Gorsuch Urges Corps of Engineers Lead on Engineering, Design for Site Cleanup," Bureau of National Affairs, July 31, 1981, pp. 427-428.

EPA, 1980a, "Research Summary - Controlling Hazardous Wastes," EPA-600/8-80-017, May 1980.

__________, 1980b, "Questions and Answers on Hazardous Waste Regulations With Guide to May 19, 1980, Federal Register," SW-853, Environmental Protection Agency.

__________, 1980c, Preamble to Hazardous Waste Management Regulations 40 CFR 260-265 as published in Federal Register, Environmental Protection Agency, May 1980.

__________, 1980d, "Hazardous Waste Information," SW-737, Environmental Protection Agency, June 1980.

__________, 1980e, "Attack on Hazardous Waste: The Challenge of the 1980's," SW-845, Environmental Protection Agency, August 1980.

__________, 1980f, "Hazardous Waste Generation and Commercial Hazardous Waste Management Capacity, An Assessment," SW-984, Environmental Protection Agency, December 1980.

__________, 1981, "Agenda of Regulations," Federal Register, Environmental Protection Agency, April 27, 1981, p. 23692.

GAO, 1981, "Hazardous Waste Sites Pose Investigation, Evaluation, Scientific, and Legal Problems," CED-81-57, Comptroller General, General Accounting Office of the United States, April 24, 1981.

Gorsuch, A., 1981, "EPA Releases Cleanup Funds for Two Sites," Hazardous Waste Report, Vol. 2, No. 23, June 15, 1981.

Kraybill, D., T. Mullen, and B. Donahue, 1980, "Hazardous Waste Surveys of Two Army Installations and an Army Hospital," CERL-TR-N-90, U.S. Army Corps of Engineers, Construction Engineering Research Laboratory, Champaign, Illinois, August 1980.

REFERENCES (Continued)

Looby, T.P., and R. Shukle, 1981, Testimony Before the Senate Subcommittee on Environmental Pollution Relating to Rocky Mountain Arsenal, Washington, D.C., July 20, 1981.

Malone, P.B., and R.J. Larson, 1980, "Solidification/Stabilization of Military Wastes," Proceedings of 11th Annual Environmental Systems Symposium, American Defense Preparedness Association, Arlington, Virginia, November 19-20, 1980.

Marienthal, G.A., 1980, Deputy Assistant Secretary of Defense (Energy, Environment, and Safety), Testimony Before the Judiciary Committee and the Subcommittee on Health and Scientific Research of the Committee on Labor and Human Resources, June 6, 1980.

__________, 1981, Deputy Assistant Secretary of Defense (Energy, Environment, and Safety), Statement Before the Subcommittee on Environmental Pollution of the Environment and Public Works Committee, United States Senate, July 20, 1981.

NEESA, 1978, "Management of Hazardous Waste Disposal in the U.S. Navy," NESO-15-01, Naval Energy and Environmental Support Activity (formerly Naval Environmental Support Office), December 1978.

USAEDH, 1980, "Operations Manual for Army Pollution Abatement Program (APAP)," HNDM-1110-1-3, U.S. Army Corps of Engineers, Huntsville, Alabama, Division, September 9, 1980.

ABBREVIATIONS

AEA	Atomic Energy Act
AFB	Air Force Base
AFESC	Air Force Engineering Services Center (Tyndall AFB, Florida)
AFMSC	Air Force Medical Services Center
AFRCE	Air Force Regional Civil Engineers
AFSG	Air Force Surgeon General
CAA	Clean Air Act
CERL	Construction Engineering Research Laboratory (COE)
CFR	Code of Federal Regulations
COE	Corps of Engineers
CWA	Clean Water Act
DARCOM	Army Materiel Development and Readiness Command
DASG-ZA	Department of the Army - Surgeon General
DEQPPM	Defense Environmental Quality Program Policy Memorandum
DLA	Defense Logistics Agency
DOD	Department of Defense
DOT	Department of Transportation
DPDO	Defense Property Disposal Office
DPDS	Defense Property Disposal Service
DRE	destruction and removal efficiency
EF	Facilities, Environment, and Economic Adjustment Office
E.O.	Executive Order
EP	extraction procedure
EPA	Environmental Protection Agency
FORSCOM	U.S. Army Forces Command
FR	Federal Regulation
HMTA	Hazardous Materials Transportation Act
HMTC	Hazardous Materials Technical Center
IRP	Installation Restoration Program
LE	Deputy Chief of Staff for Logistics and Engineering
LOG	Air Force Logistics Command
MRA-L	Assistant Secretary for Manpower, Reserve Affairs and Logistics
NAVFAC	Naval Facilities Engineering Command - Energy and Environment
NAVMAT	Naval Material Command
NAVSUP	Naval Supply Systems Command
NCP	National Contingency Plan
NEESA	Naval Energy and Environmental Support Activity (Port Hueneme, California)
NEPA	National Environmental Policy Act
NESHAPS	National Emissions Standards for Hazardous Air Pollutants

ABBREVIATIONS (Continued)

NOP-04	Chief of Naval Operations - Logistics
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
OEHL	Occupational and Environmental Health Laboratory (USAF)
OSHA	Occupational Safety and Health Act
PCB	polychlorinated biphenyls
PMN	premanufacturing notification
RCRA	Resource Conservation and Recovery Act
R&D	research and development
R-E	Under Secretary for Research and Engineering
SAIL & FM	Secretary of the Army, Installations, Logistics, and Financial Management
SDWA	Safe Drinking Water Act
SPCC	spill prevention, control, and countermeasure
TSCA	Toxic Substances Control Act
TSD	treatment, storage, and disposal
USAEHA	U.S. Army Environmental Hygiene Agency
USAMBRDL	U.S. Army Medical Bioengineering Research and Development Laboratory
USATHAMA	U.S. Army Toxic and Hazardous Material Agency

APPENDIX A. EXAMPLES OF HAZARDOUS WASTE STREAMS FROM MILITARY INSTALLATIONS

The kinds of wastes generated at military facilities are listed by general classification and are directly related to overall mission, specific tenant, and industrial activities. Some examples of typical military operations and processes generating large quantities of hazardous wastes are listed below. This is not meant to be a comprehensive listing.

Base Industrial-Related Operation/Process	Hazardous Wastes
Metal plating	Acids Pickling liquor Caustics Spent cyanide solutions Chromium wastes Other metal wastes
Degreasing	Solvents (e.g., trichloroethylene, methylethylketone (MEK))
Painting and stripping	Paint strippers Paint thinners Paint wastes (slops) Waste epoxy (resin)
Machine shops	Cutting oils Toxic metals
Miscellaneous aircraft repair wastes	Brake relining wastes (beryllium wastes Metal stress and defect analysis wastes (fluorescent dye) Welding wastes (acetylene sludge)
Fuel storage and supply	Waste (or slop) oil Bunker oil Fuel waste Tank bottom sediment Tank cleaning sludges
Transportation	Waste oils Hydraulic fluids Battery acids Asbestos (brake linings) Ethylene glycol (coolants) Paint waste Solvents

Base Support Operation/Process	Hazardous Wastes
Cooling towers	Bleedoff wastes Feedwater chemicals
Boilers	Blowdown wastes (e.g., hydrazine, morphaline) Feedwater chemicals Feedwater testing wastes (e.g., mercuric nitrate)
Pest control shops	Unrinsed pesticide containers Waste pesticides Equipment wash water
Battery shop	Battery acids Alkaline battery fluid Heavy metals
Disaster preparedness	Supertropical bleach Decontaminating gases (ethylene oxide) Decontaminating liquids (DS-2, DANC)
Carpenter and woodworking shops	Sawdust from pressure treated wood (pentachlorophenol, copper cadmium arsenic, creosote)
Print shop, ADP center	Printing ink Data processing fluid
Other operations/ processes	Ordnance wastes (e.g., TNT, RDX, picric acid, liquid rocket propellant) Photograph wastes Transformer fluids (PCBs) Industrial Waste Treatment Plant sludge Laboratory wastes Firefighting agents (e.g., aqueous film fire fighting treatment, AFFF) Chemical toilet waste Chemical cleaners Demolition Protective coating Plastics fabrication

Sources: Naval Energy and Environmental Support Activity and Air Force Engineering and Services Center

APPENDIX B. SUMMARY OF ENVIRONMENTAL PROTECTION AGENCY HAZARDOUS WASTE MANAGEMENT REGULATIONS

The following discussion presents Environmental Protection Agency (EPA) regulations only and does not include impacts or interpretations specific to the Department of Defense (DOD).

B.1 LAWS AND REGULATIONS CONCERNED WITH HAZARDOUS WASTE MANAGEMENT

During the 1970s, a number of hazardous waste laws and regulations came into existence. A summary of the major Federal hazardous waste laws, their implementing regulations, and their requirements for DOD hazardous waste management are provided in Table B-1. Because Subtitle C of the Resource Conservation and Recovery Act (RCRA) is the major piece of legislation implementing hazardous waste management, a detailed description of its regulations is included in this appendix.

B.2 SUMMARY OF REGULATIONS IMPLEMENTING SUBTITLE C OF RCRA

Subtitle C of RCRA establishes a Federal program to provide comprehensive regulation of hazardous waste. When fully implemented, this program will provide "cradle-to-grave" regulation. Section 3001 of Subtitle C directs EPA to identify the characteristics of and to list those hazardous wastes that are subject to regulation under Subtitle C. Sections 3002 and 3003 require EPA to establish standards for generators and transporters of hazardous waste that will ensure proper recordkeeping and reporting; the use of a manifest system to track shipments of hazardous waste; the use of proper labels and containers; and the delivery of the waste to properly permitted treatment, storage, and disposal (TSD) facilities. To ensure that these facilities are designed, constructed, and operated in a manner that protects human health and the environment, Section 3004 of RCRA directs EPA to promulgate technical, administrative, monitoring, and financial standards for them. These independently enforceable standards will be used by EPA to issue permits to owners and operators of facilities under Section 3005. For those states interested in administering the RCRA program, Section 3006 requires EPA to issue guidelines under which states may seek authorization to carry out the program. Finally, under Section 3010, all persons engaging in activities subject to control under Sections 3002 through 3004 above must notify EPA or states having authorized RCRA hazardous waste programs.

Table B-1. Summary of Important Federal Legislation Controlling Hazardous Waste

Law	Concern With Hazardous Waste Management	Applicable Regulations	Summary of Regulations	DOD Requirements
Resource Conservation and Recovery Act	Establishes the hazardous waste management program (Subtitle C)	40 CFR 260	Definitions generally used throughout the regulations.	Applicable to DOD and its management of waste.
		40 CFR 261	Identification and listing of hazardous waste.	Some wastes generated by DOD.
				Describes testing procedures so DOD can determine nature of waste.
				Small-quantity generators (those who generate $\geq$1000 kg/mo) are excluded from regulation.
		40 CFR 262	Standards applicable to generators of hazardous waste.	Test wastes and determine if they are hazardous.
				Notify EPA of generation of hazardous waste and obtain identification (ID) number.
				Submit annual report detailing waste generation
				Prepare manifest for offsite transportation.
		40 CFR 263	Standards applicable to transporters of hazardous waste.	Notify EPA and obtain ID number.
				Comply with manifest directions.
				Clean up and report spills.
		40 CFR 264	Standards applicable to owners and operators of treatment, storage, and disposal (TSD) facilities.	New (constructed after Nov. 19, 1980) facilities must comply with general requirements and facility-specific standards.
				Obtain ID number and permit to operate.
				Analyze wastes.
				Submit reports.

Table B-1. Summary of Important Federal Legislation Controlling Hazardous Waste (Continued)

Law	Concern With Hazardous Waste Management	Applicable Regulations	Summary of Regulations	DOD Requirements
Resource Conservation and Recovery Act (Continued)		40 CFR 265	Interim status standards for owners and operators of existing (constructed before Nov. 19, 1980) TSD facilities. Specific deadlines were given for compliance activities (notification by Aug. 18, 1980. Part A of permit submitted by Nov. 19, 1980).	Existing facilities must comply with general requirements and facility-specific standards. Obtain ID number and permit to operate. Submit reports.
		40 CFR 122 and 124	Describes information needed and procedures for obtaining permits for TSD facilities. Part of the EPA consolidated permit regulations.	Submit permit applications and obtain a permit to operate.
		40 CFR 123	Establishes requirements for states' to manage hazardous waste.	Comply with state regulations and standards in those states that have hazardous waste management programs approved by EPA.
Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)	Establishes Federal authority to respond to releases or threats of releases of hazardous substances from facilities and to inventory hazardous waste sites. Establishes a taxation and fund system to help clean up existing sites whose owners cannot be determined.	40 FR 22143, April 15, 1981	Form for reporting hazardous waste sites (form 8900-1).	Notify EPA of existence of facilities that did or currently do treat, store, or dispose of hazardous substances. Responsible parties must clean up dumps.
		E.O. 12316, 46 FR 42237	Clarifies Federal responsibilities under Superfund.	DOD is a member of national response team, is a Federal trustee for natural resources, and is responsible for releases from DOD facilities or vessels.
Hazardous Materials Transportation Act	Establishes standards to be used in transporting hazardous wastes, both intrastate and interstate.	49 CFR 171-179	Defines labeling, marking, placarding, and use of proper containers and procedures for reporting spills and accidents. Department of Transportation (DOT) has authority for implementation.	Ensure that wastes are properly labeled, etc., prior to transporting offsite. Report accidental spills or discharges to DOT.

Table B-1. Summary of Important Federal Legislation Controlling Hazardous Waste (Continued)

Law	Concern With Hazardous Waste Management	Applicable Regulations	Summary of Regulations	DOD Requirements
Toxic Substances Control Act	Describes handling of polychlorinated biphenyls (PCBs) and sets performance standards for PCB disposal.	40 CFR 761	PCBs are to be treated by incineration. The destruction and removal efficiency (DRE) must be 99.9999%. Other suitable treatment/disposal alternatives may be authorized by EPA (e.g., Sunohio chemical destruction method).	Dispose of PCBs in facilities (incinerator) permitted and designed to achieve a DRE of 99.9999%.
Safe Drinking Water Act	Authorizes EPA to establish standards and permit conditions for wells that inject hazardous waste into the ground.	40 CFR 122, 124, and 146	An injection well, designed and operated in accordance with the standards, that disposes of hazardous waste must obtain an underground injection control (UIC) permit.	Obtain a UIC permit for any facility involved in injecting hazardous waste underground. Also obtain an RCRA permit for any portion of the aboveground facility involved in treating or storing the waste prior to injection.
Clean Water Act	Authorizes (Section 307(a)) EPA to identify toxic pollutants and to regulate the discharge of those pollutants into U.S. waters.	40 CFR 122, 124, and 125	Discharges of wastewater containing any of the priority pollutants or other toxic pollutants identified by EPA are regulated under the National Pollutant Discharge Elimination System (NPDES) process.	Obtain an NPDES permit for any facility discharging a listed toxic wastewater pollutant into a body of water. Use Best Management Practices (BMP) to prevent release of hazardous pollutants.
		40 CFR 116 and 117	Identifies 299 hazardous substances, and provides requirements for reporting spills.	Report a spill of any of the 299 listed substances to EPA immediately.
		40 CFR 251	Requires development of a Spill Prevention, Control, and Countermeasure (SPCC) Plan for facilities with an NPDES permit.	NPDES-permitted facilities must prepare an SPCC plan.
Clean Air Act	Emissions of certain listed hazardous air pollutants are regulated.	40 CFR 61	Emissions of the listed hazardous pollutants must be permitted under CAA. National Emissions Standards for Hazardous Air Pollutants (NESHAPS) are set for asbestos, beryllium, mercury, and vinyl chloride. Radionuclides and benzene are listed but do not have NESHAPS.	Any facility that emits one or more of the hazardous air pollutants must meet NESHAPS and obtain a CAA permit.
Occupational Safety and Health Act	Sets exposure limits to hazardous materials in workplace environment.	29 CFR 1910.1000	Exposure limits, safety equipment, handling procedures, and monitoring and recordkeeping standards are set for the workplace environment.	Ensure that OSHA workplace standards are met in areas where hazardous materials are handled.

B.2.1 Hazardous Waste Management Program Organization

The regulations implementing Subtitle C of RCRA are codified in 40 CFR 260 through 265 and 40 CFR 122, 123, and 124. A brief summary of the regulations is provided in Table B-1. The dates of publication in the Federal Register of major regulations are provided in Table B-2.

B.2.2 Identification of Hazardous Wastes

Because no material can be a hazardous waste without first being a solid waste, what constitutes a solid waste is really the definitional starting point. Section 1004(27) of RCRA defines a solid waste as

> any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial or mining and agricultural operations, and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows, or industrial discharges which are point sources subject to permits under section 402 of the Federal Water Pollution Control Act . . . or source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954 . . . (Section 1004(27)).

In its regulations, EPA adopted this definition, with its exclusions, in its entirety. In addition, it defined the term "other discarded material" in Section 1004(27) to include

- Any material that is not reused, i.e., is abandoned or committed to final disposal
- Any material that is reused by being placed in or on the land or water such that the material or any constituent of it is released into the environment
- Waste oil burned as fuel

A solid waste is hazardous if it is "not excluded under Section 261.4(b) and it either (1) is listed as a hazardous waste in Subpart D, (2) is a waste mixture containing one or more hazardous wastes listed in Subpart D, or (3) exhibits one or more characteristics of hazardous waste identified in Subpart C."

Table B-2. Major RCRA Regulations Governing Hazardous Waste Management

Summary of Regulation	CFR Citation	Federal Register Publication Date
Basis of regulatory framework and standards for generators, transporters, and owners/operators of TSD facilities	40 CFR 260-265	May 19, 1980
Additional rules on identification and listing of wastes	40 CFR 261	July 16, 1980
Final lists of hazardous wastes	40 CFR 261	Nov. 12, 1980
Amendments to exemptions for small-quantity generators and generator accumulation	40 CFR 261	Nov. 19, 1980
Clarification of container regulations; final list of commercial products that are hazardous if discarded	40 CFR 261, 262, and 265	Nov. 25, 1980
Storage by transporters; shipments from TSD facilities; transportation by rail	40 CFR 263	Dec. 31, 1980
Additional general requirements for TSD facilities; closure and post-closure care and financial responsibility; amendments to permitting requirements	40 CFR 264 40 CFR 265 40 CFR 122	Jan. 12, 1981
Incinerator standards for owners and operators	40 CFR 264, 265, and 122	Jan. 23, 1981
Proposed standards applicable to owners and operators of new landfills, land treatment, disposal piles, disposal impoundments, and underground injection facilities	40 CFR 264	Feb. 5, 1981
Temporary standards for landfills, land treatment, disposal impoundments, and underground injection facilities	40 CFR 267 and 122	Feb. 13, 1981
Special requirements for ignitable or reactive waste	40 CFR 265	Feb. 20, 1981

The following solid wastes are the "excluded hazardous wastes" referred to in the definition:

- Household waste
- Wastes that are reused or recycled, except for the storage and transportation of sludges and listed wastes
- Agricultural wastes returned to the soil as fertilizers or soil conditioners
- Mining overburden returned to the mine site
- Utility wastes (fly ash, flue gas desulfurization sludge, bottom ash)
- Oil and gas drilling muds and brines

A list of hazardous wastes is included as 40 CFR 261 Subpart D. If a waste is not on the list, it must be tested to see if it shows at least one of the four characteristics of hazardous waste:

- Ignitability -- Posing a fire hazard during routine management
- Corrosivity -- Ability to corrode standard containers or to dissolve toxic components of other wastes
- Reactivity -- Tendency to explode under normal management conditions, to react violently when mixed with water, or to generate toxic gases
- EP toxicity (as determined by a specific extraction procedure) -- Presence of certain toxic materials at levels greater than those specified in the regulation

Certain groups are still exempt from the hazardous waste regulations. The regulation provides for the exemption of small generators from these initial hazardous waste controls. In general, facilities generating or accumulating less than 1000 kilograms per month of an identified hazardous waste are exempted; however, EPA has specified lower generation limits for certain acutely hazardous wastes. To enjoy this exemption, however, small generators must dispose of their hazardous waste in approved Subtitle C hazardous waste management facilities or in facilities approved by a state to manage municipal or industrial solid waste. In addition, it is possible for the generator to get an exemption from regulation even if the waste is listed in the regulation. Regulation 40 CFR Part 260 includes delisting procedures for generators who believe their facility's individual waste is fundamentally different from the waste listed. The generator must demonstrate, or must cite test data that demonstrate, that the specific

waste does not meet the criteria that caused EPA to list the waste. This provision recognizes that individual waste streams vary depending on raw materials, industrial processes, and other factors.

B.2.3 Standards Applicable to Generators of Hazardous Waste

Anyone who generates hazardous waste is required to notify EPA within 90 days of promulgation of the identification regulation (August 18, 1980). A generator who notified EPA during the 90-day period received an identification (ID) number. New generators (those not generating hazardous waste during this 90-day period) must obtain an ID number within 90 days of beginning operation. Requests for an ID number should be submitted to the appropriate EPA regional office.

For waste leaving the site where it was generated, the generator must

- Use only transporters with ID numbers
- Prepare a manifest (shipping form) for all movements of hazardous waste sent to offsite TSD facilities
- Keep records of these shipments
- Report shipments that do not reach the facility designated on the manifest

The manifest is a shipping document that accompanies hazardous waste that is being transported. A generator of hazardous waste is responsible for preparing a manifest containing

- Name and address of the generator
- Names of all transporters
- Name and address of the permitted facility designated to receive the waste (an alternate facility may be designated if an emergency prevents use of the first facility)
- EPA ID numbers of all who handle the waste
- Department of Transportation (DOT) description of the waste
- Quantity of waste and number of containers
- Generator's signature certifying that the waste has been properly labeled, marked, and packaged in accordance with DOT and EPA regulations

The generator signs the certification on the manifest, including one copy for each person handling the waste. The transporter then signs and dates the manifest and returns one copy to the generator, who retains it until a copy is received from the designated facility following delivery of the waste.

Generators who accumulate waste on their property more than 90 days are considered to be storing waste and are required to obtain a facility permit under Section 3005 of RCRA. The date accumulation began must be clearly marked on the container. A generator who treats, stores, or disposes of waste onsite will be subject to the requirements of Sections 3004 and 3005 of RCRA.

B.2.4 Transporter Responsibilities

Anyone who transports hazardous waste was required to notify EPA within 90 days of promulgation of the identification regulation (by August 18, 1980). A transporter who notified EPA during the 90-day period following promulgation of the identification regulation received an ID number. New transporters (those not handling hazardous waste during this 90-day period) may submit requests for an ID number to their EPA regional office. A generator of hazardous waste is prohibited from using the services of a transporter who does not have an EPA ID number.

The generator packages the wastes according to DOT regulations and prepares the manifest. The transporter signs and dates the manifest and returns one copy to the generator, who retains it until a copy is received from the designated permitted facility following delivery of the waste. The transporter carries the manifest with the wastes to the designated facility. When the shipment arrives, an agent for the facility signs and dates each copy and retains one. One copy is given to the transporter, who retains it for 3 years, and another copy is returned to the generator by the facility agent. If more than one transporter is involved, the initial transporter must obtain the subsequent transporter's dated signature on the manifest. The remaining copies accompany the waste until it reaches the designated facility.

For rail shipment or bulk shipment by water, the manifest need not accompany the waste. However, a shipping paper, which contains all the information on the manifest except EPA ID numbers, generator certification, and signatures, must accompany the waste. If transportation other than rail or water is used at any stage of the shipping process, the manifest must accompany the waste at all times.

The waste may be transferred between two rail or bulk shipment water carriers without obtaining the subsequent carrier's signature. But the final rail or water transporter must obtain the dated signature

of the agent for the designated facility on the shipping paper or the manifest. All rail or water transporters are required to keep a copy of the shipping paper or the manifest for 3 years from the date of acceptance.

All transporters are responsible for cleaning up any discharge of hazardous waste that occurs during transportation. When authorities on the scene declare an emergency, they can temporarily suspend the requirement that waste can be handled only by those holding EPA ID numbers and complying with the manifest system. This suspension ceases when the emergency no longer exists. A written report of each discharge must be submitted to DOT, which will forward a copy to EPA.

B.2.5 Responsibilities of Owners and Operators of Hazardous Waste TSD Facilities

Owners and operators of hazardous waste TSD facilities must comply with the standards promulgated under Section 40 CFR Parts 264 or 265. The regulations under this section, which set standards for hazardous waste facilities, serve a threefold purpose:

- To establish proper TSD practices
- To provide states with minimum standards in order to receive EPA approval for this facet of their hazardous waste programs
- To provide the technical basis for EPA-issued facility permits in states that do not operate an RCRA program

EPA is promulgating standards for hazardous waste facilities in two phases: Phase I -- interim status standards (40 CFR 265) and Phase II -- permanent status standards (40 CFR 264).

"Interim status" gives existing hazardous waste facilities temporary authority to continue operations pending final administrative action on facility permit applications. Existing facilities are those that were operating or for which construction had commenced prior to November 19, 1980. To qualify for interim status, a facility had to

- Notify EPA of its operations by August 18, 1980
- Submit Part A of the two-part permit application form by November 19, 1980
- Meet the requirements of the interim status standards (40 CFR 265)

Permanent status standards were promulgated in several parts. The general requirements were published on May 19, 1980, with the majority of the hazardous waste regulations. Standards specific to certain facilities were promulgated in January and February 1981.

AD-A113 741 AEROSPACE CORP GERMANTOWN MD ENVIRONMENT AND ENERGY --ETC F/G 13/2
MILITARY HAZARDOUS WASTES: AN OVERVIEW AND ANALYSIS.(U)
DEC 81 K E KAWAOKA, M C MALLOY, G L DEVER
UNCLASSIFIED ATR-81(8376)-1 NL

2
AD
A113741

END
DATE
FILMED
5-82
DTIC

The following general administrative and facility requirements are similar to both interim status and final status standards:

- Waste analysis -- Detailed chemical and physical analyses, waste analysis plan, specific requirements for each facility type
- Security -- Artificial or natural barrier with controlled entry or 24-hour surveillance and warning signs
- Inspection -- Inspection plan and log and remedy of any deterioration, malfunction, or imminent hazard
- Personnel training -- Classroom or on-the-job training, annual review of initial training, records of personnel training
- Preparedness and prevention -- Alarm system and emergency equipment and arrangements with local emergency authorities
- Contingency plan, emergency procedures, and emergency coordinator
- Manifest system procedures
- Operating records of activities required by the regulation, such as manifest information, waste analysis records, testing and analytical data, and demonstration reports for variances
- Reporting requirements, such as annual reports and unmanifested waste reports
- General operating requirements
- Special requirements for ignitable, reactive, and incompatible wastes
- Groundwater monitoring
- Closure and postclosure plans -- Estimate of costs and description of how facility will be closed, notice of facility closure, and postclosure monitoring and maintenance

General final standards also include siting requirements, as follows:

- New facilities should not be located within 61 meters (200 feet) of a fault that has displaced in Holocene time.
- New facilities located in the 100-year floodplain must be designed, constructed, and operated to prevent washout by a 100-year flood.

A summary of promulgation dates for final facility-specific standards is presented in Table B-3. Also to be promulgated as part of Phase II are selective standards for uranium and phosphate radioactive wastes and for waste oil (Part 266), which will consist of restrictions on the uses of these wastes and closure requirements. Further technical refinements will be promulgated by EPA intermittently over a period of years. These will include the resolution of complex

Table B-3. Summary of Promulgation Dates for Facility-Specific Standards

40 CFR 264 Subpart	Title	Federal Register Publication Date(s)
I 264.170- 264.178	Use and management of containers	January 12, 1981
J 264.190- 264.199	Tanks	January 12, 1981
K[a] 264.220- 264.230	Surface impoundments	January 12, 1981 February 13, 1981
L 264.250- 264.258	Waste piles	January 12, 1981
M[a] 264.270- 264.283	Land treatment	February 5, 1981 February 13, 1981
N[a] 264.300- 264.316	Landfills	February 5, 1981 February 13, 1981
O 264.340- 264.351	Incinerators	January 23, 1981
R[a] 264.430- 264.434	Underground injection	February 5, 1981
S 264.460- 264.470	Seepage facilities	February 5, 1981

[a] Standards for using these facilities for disposal are proposed. EPA therefore cannot issue permits for these facilities. Consequently, on February 13, 1981, EPA published temporary standards, which will be used until the proposed standards become final. These temporary standards are codified in 40 CFR 267.

technical issues and the reproposal and promulgation of more definitive Phase II standards, for example, specific design or operating standards for incinerators and landfills. The technical refinements may also include standards for specific industries and wastes that require tailored standards.

B.2.6 Permit System

Any person who owns, operates, or proposes to own or operate a facility that treats, stores, or disposes of hazardous waste must receive a permit from EPA or a state authorized to conduct its own hazardous waste program. Most requirements in the regulation are only applicable where EPA issues permits; selected portions apply to authorized state programs. Certain facilities handling hazardous waste do not require an RCRA permit:

- Generators who accumulate hazardous waste onsite for less than 90 days
- Farmers who dispose of hazardous waste pesticides from their own use
- Those who own or operate facilities solely for the treatment, storage, or disposal of certain hazardous waste excluded from regulation

Anyone who owns or operates a hazardous waste facility must apply for a permit. The application is in two parts:

- Part A, which defines the processes to be used, the design capability, and the hazardous waste to be handled. For existing facilities, Part A was to be submitted by November 19, 1980.
- Part B, which contains more detailed information intended to establish that the facility can meet the technical standards. For existing facilities, Part B must be submitted at a date set by the Regional Administrator.

For proposed new facilities, both Part A and Part B must be submitted at least 180 days before physical construction is scheduled to begin.

The Regional Administrator reviews an application for completeness. When an application is completed, the public is informed. If the Regional Administrator decides to issue a permit, a draft permit is prepared and then is subject to public notice, public comment, and in some cases, public hearings. After the comment period, EPA issues a final decision on a permit, along with a response to all significant comments.

RCRA permits are effective for a fixed term not to exceed 10 years. The Regional Administrator may review a permit at any time to determine if it should be modified, revoked and reissued, or terminated.

B.2.7 State Programs

Congress prefers that states assume responsibility for controlling hazardous wastes within their borders. Federal financial assistance is available from EPA to states for developing their programs. Section 3006 of RCRA specifically provides for states to operate their own hazardous waste programs in lieu of the Federal program, after authorization by EPA. In states whose programs do not meet the minimum requirements under RCRA, EPA must administer the program. RCRA generally directs that to receive EPA "final" approval, state hazardous waste programs must be "equivalent to and consistent with" the Federal program. "Equivalent" is interpreted to mean "equal in effect." Thus, the regulations provide minimum requirements, with the states allowed to set more stringent standards. Another important element is that states may not impose any requirement that might interfere with the free movement of hazardous wastes across state boundaries to TSD facilities holding an RCRA permit.

The following 21 states have received EPA approval to implement Phase I, which is essentially those regulations promulgated by EPA on May 19, 1980, and the amendments to those regulations:*

Alabama	Montana
Arkansas	North Carolina
California	North Dakota
Delaware	Oklahoma
Georgia	Pennsylvania
Iowa	Rhode Island
Kentucky	South Carolina
Louisiana	Texas
Maine	Utah
Massachusetts	Vermont
Mississippi	

Several other states have submitted draft Phase I programs. These will be approved within the next several months. Texas is the only state that has submitted a program for Phase II, which would give the state authority to approve permits for new hazardous waste facilities, such as incinerators, waste piles, and impoundments.

---

* This list is current as of June 20, 1981. It must be noted that the list will grow over the next few months. Additionally, states will begin to achieve approval for Phase II implementation. An update may be received by calling (202) 382-2230 (Alan Maples).

B.2.8 Anticipated Changes and Additions to RCRA Regulations

EPA periodically reviews its regulations and implements changes as warranted. Additionally, EPA is still involved in proposing regulations to implement RCRA. A summary of the significant RCRA regulations under consideration is provided in Table B-4.

The Office of Management and Budget (OMB) required EPA to evaluate and review the reporting and recordkeeping requirements associated with the RCRA standards for generators; transporters; and TSD facilities. Final proposals for paperwork reduction should be published during September 1981. EPA has focused on the following reporting requirements:

- EPA plans to eliminate the current requirement that all generators, owners, and operators of hazardous waste facilities file an annual report summarizing their activities related to hazardous waste management. EPA plans to substitute an annual survey that would be sent to a sample number of generators and facilities.

- EPA expects to develop a uniform manifest form. This manifest would be used by everyone, thereby deleting the problems associated with each state having its own specific form.

- Using a "class of hazard" approach, EPA plans to reduce the information requirements for permit applications and procedures for low-risk storage facilities. Part B permit applications and permitting procedures would be tailored to the degree of risk posed by the storage facility.

- EPA is considering reducing the number of handling codes used in the operating record from 85 to 13 and deleting the requirement that each facility maintain the record at the facility.

- EPA will review groundwater monitoring requirements but does not expect to make major changes that would reduce groundwater monitoring requirements.

- EPA plans to eliminate the requirement that postclosure cost estimates be adjusted to reflect changes in the postclosure plan during the postclosure period.

- Finally, less stringent contingency plans will be required of facilities handling wastes that pose lower risks of unplanned emergencies (e.g., nonignitable wastes).

Table B-4. Significant RCRA Regulations Under Consideration by EPA

Title	Resource Conservation and Recovery Act Summary	Contact	Timetable
Identification and Listing of Hazardous Waste SAN No. 1191 Docket No. 3001	Description: This regulation defines wastes that EPA or the States will control under the nationwide hazardous waste management program. It defines criteria for identifying characteristics of hazardous wastes based on ignitability, corrosivity, reactivity, and extract procedure toxicity. It also defines criteria for listing hazardous wastes. It provides definitions of hazardous wastes characteristics and lists of hazardous wastes. Future promulgations may include additional listed hazardous wastes as well as necessary changes or additions to other parts of Part 261 (in response to comments, field operations, etc.) Classification: Major Statutory Authority: RCRA 3001/42 USC 6921 CFR Change: 40 CFR 261 - New Analysis: EIS, ORA	Alan Corson EPA (WH-565) Washington DC 20460 FTS:8-755-9187 COMM:202-755-9187	NPRM:43FR58946 (12/18/78) FR: 45FR33084 (05/19/80) FR: 45FR47835 (07/16/80) FR: 45FR74884 (11/12/80) IFR: 45FR76620 (11/19/80) FR: 45FR78524 (11/25/80) IFR: 45FR80286 (12/04/80) FR: 46FR4614 (01/16/81) IFR: 05/00/81
Revisions of Proposed Listing of Waste Oil as a Hazardous Waste; Revision of Proposed Waste Oil Regulations SAN No. 1713 Docket No. 3012	Description: In 1978, EPA proposed the listing of certain waste oils as hazardous wastes and proposed a set of standards applicable to the transportation, storage, treatment, recycling and disposal of these and other waste oils. EPA is reproposing this listing and the corresponding regulations because of the many new and revised provisions which have not been subjected to public review. Classification: Other Statutory Authority: RCRA 3001/42 USC 6921 CFR Change: 40 CFR 266 - Revision Analysis: Report, RFA	Arline M. Sheehan EPA (WH-565) Washington DC 20460 FTS:8-755-9200 COMM:202-755-9200	NPRM:43FR58946 (12/18/78) RPRM:09/00/81 FR: 03/00/82
Standards Applicable to Owners and Operators of Hazardous Waste Treatment and Disposal Facilities SAN No. 1194 Docket No. 3004	Description: This regulation requires facilities that manage hazardous waste to meet certain standards for financial responsibility, operating practices, location, and design. These standards have been set to protect the quality of air, surface-water, and groundwater. Classification: Major Statutory Authority: RCRA 3004/42 USC 6924 CFR Change: 40 CFR 264,265,266 - New Analysis: EIS, ORA	John Lehman EPA (WH-565) Washington DC 20460 FTS:8-755-9185 COMM:202-755-9185	FR: 45FR33154 (05/19/80) RPRM:46FR11126 (02/05/81) IFR: 46FR2802 (01/12/81) 45FR86966 (12/31/80) 45FR86970 (12/11/80) 46FR7666 (01/23/81) FR: 01/00/82
Guidelines for Federal Procurement of Cement and Concrete Containing Fly Ash SAN No. 1200 Docket No. 6002(e)	Description: These guidelines are to help Federal agencies ensure procured products contain as much recycled material as possible. Section 6002(e) of RCRA directs EPA to prepare these guidelines to help maximize the energy and materials that the Federal Government recovers from solid waste. The first of these guidelines will cover regulations for fly ash in cement and concrete. Classification: Other Statutory Authority: RCRA 6002(e)/42 USC 6962(e) CFR Change: 40 CFR 249 - New	John Heffelfinger EPA (WH-565) Washington DC 20460 FTS:8-755-9206 COMM:202-755-9206	NPRM:45FR76906 (11/20/80) FR: 07/00/81
Guidelines for Federal Procurement for Recycled Paper Products SAN No. 1200A	Description: RCRA directs EPA to prepare guidelines to help maximize energy and materials recovered from solid waste. This guideline gives advice to Federal purchasing agencies concerning purchasing practices which will increase the percentage of recycled paper products bought. Classification: Other Statutory Authority: RCRA 6002(e)/42 USC 6962(e) CFR Change: EPA will assign a CFR part to this regulation - New	Frank Smith EPA (WH-563) Washington DC 20460 FTS:8-755-9140 COMM:202-755-9140	NPRM:06/00/81

NPRM - Notice of Proposed Rule Making
FR - Final Rule
CFR - Code of Federal Regulations
USC - United States Code
ORA - Operations/Resource Impact Analysis
IFR - Interim Final Rule
RPRM - Re-proposed Rulemaking
RFA - Regulatory Flexibility Analysis
EIS - Environmental Impact Statement

Source: EPA, "Agenda of Regulations," Federal Register, April 27, 1981, p. 23692.

APPENDIX C. MILITARY HAZARDOUS WASTE ORGANIZATION

Figures C-1 through C-4 identify the cognizant Department of Defense (DOD) and service branch offices involved with military hazardous wastes. The charts are accompanied by a list of contacts within these offices and their responsibilities (Table C-1). It should be noted that each of the services' major commands maintains its respective environmental management program, and not all of these offices were contacted for this study.

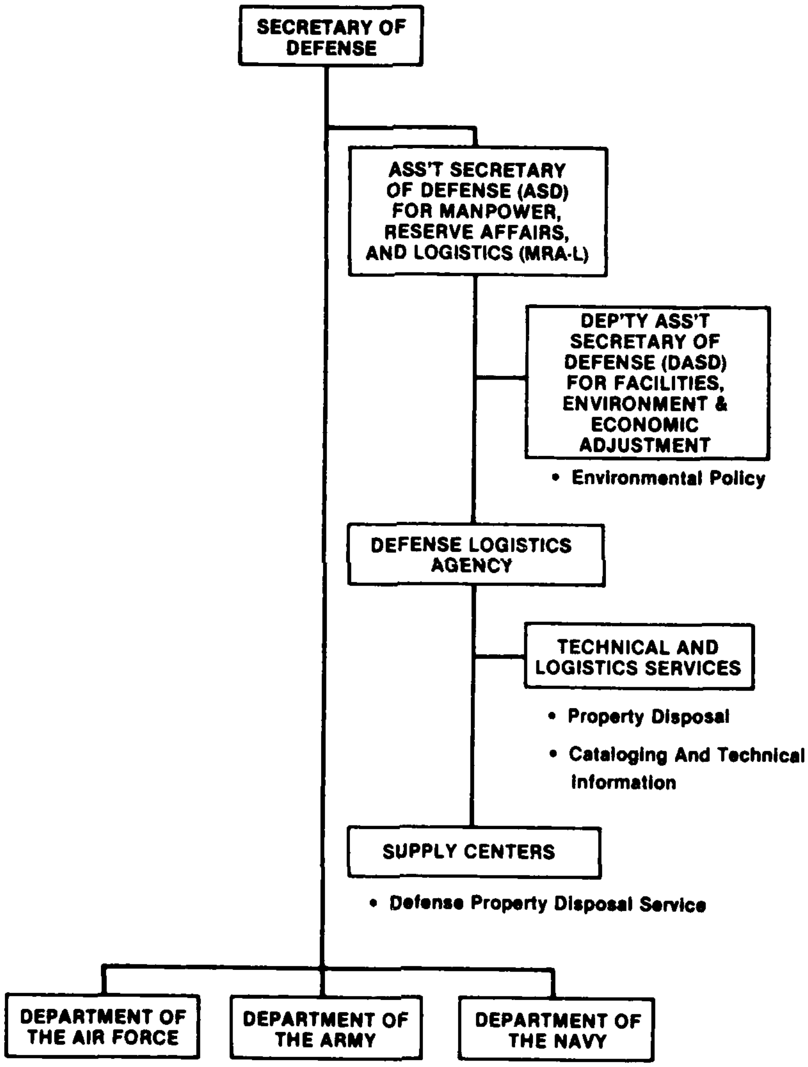


Figure C-1. Department of Defense Hazardous Waste Organization

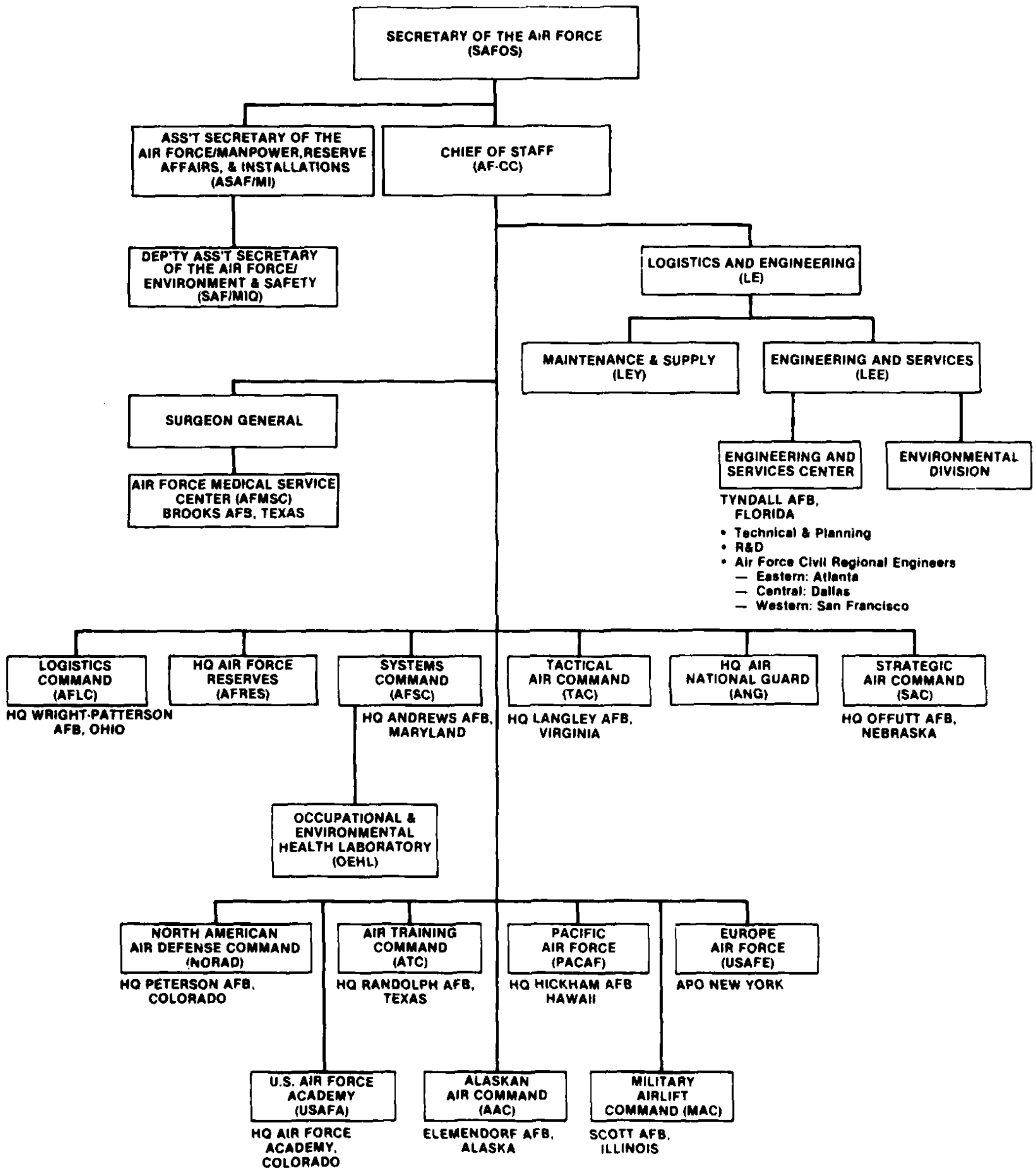


Figure C-2. Department of the Air Force Hazardous Waste Organization

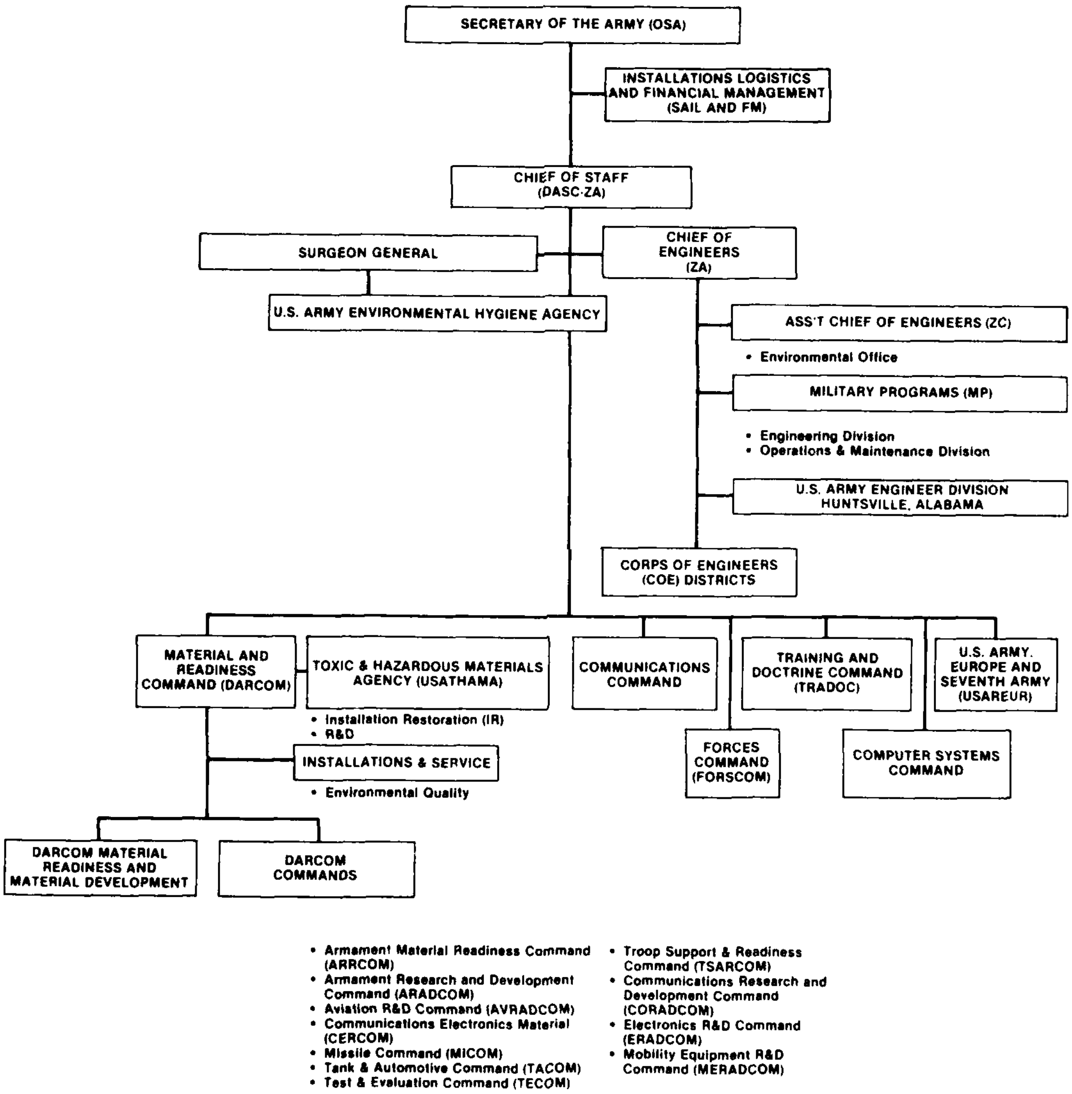


Figure C-3. Department of the Army Hazardous Waste Organization

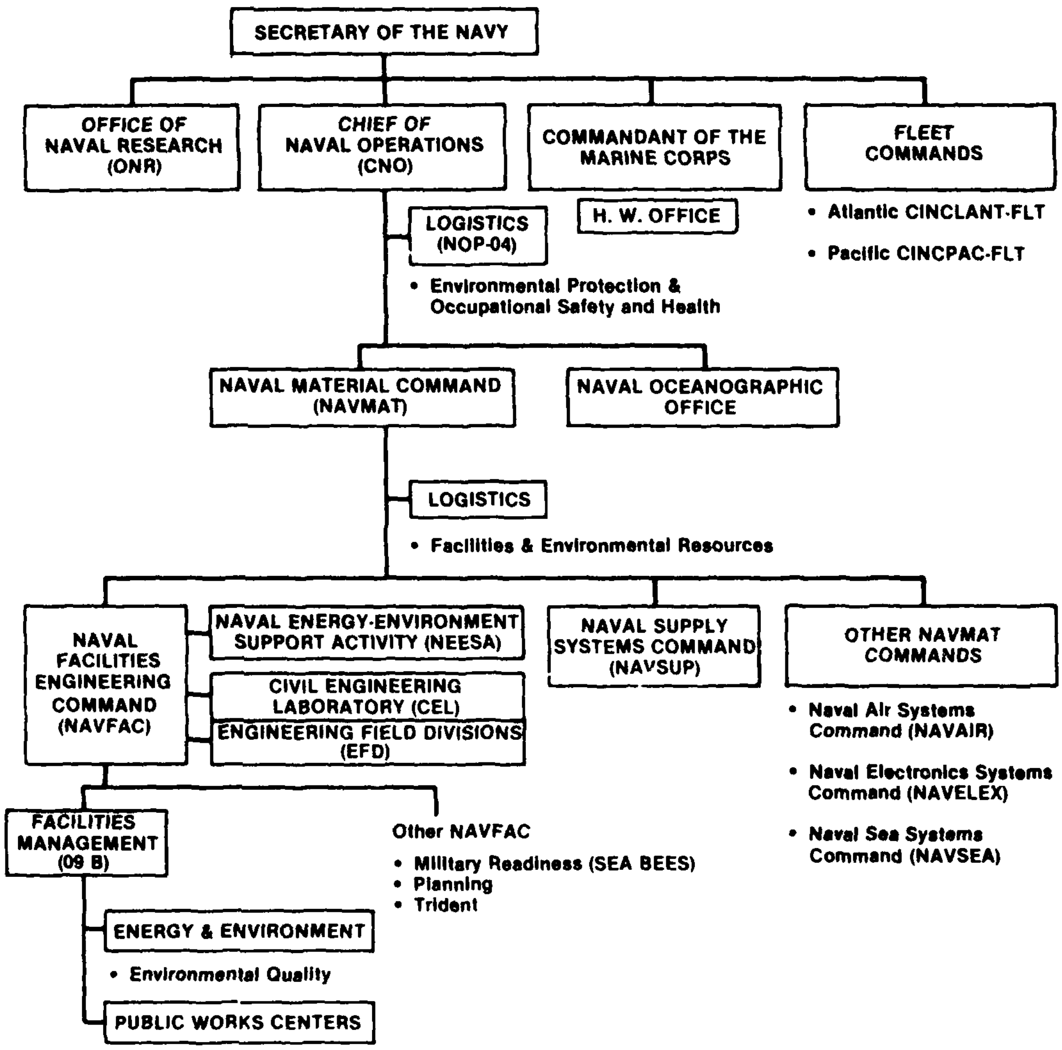


Figure C-4. Department of the Navy Hazardous Waste Organization

Table C-1. Military Hazardous Waste Contacts

Organization	Phone	Responsibility
Department of Defense		
Office of the Deputy Assistant Secretary of Defense (Facilities, Environment, & Economic Adjustment) The Pentagon, Room 3D-833 Washington, D.C. 20301	(202)695-7820	Provide DOD policy guidance and direction
Defense Logistics Agency (DLA)		
DLA Attn: DLA-SME Cameron Station Alexandria, Virginia 22314	(202) 274-7503	Establishes policy for DLA
Headquarters, DLA, Program Mgr., DOD Hazardous Materials Information System Attn: DLA-SC Cameron Station Alexandria, Virginia 22314	(202) 274-6793	Maintains Hazardous Materials Information System for DOD
Defense Property Disposal Service Directorate of Environmental Protection (DPDS-H) Federal Center Battle Creek, Michigan 49016	(616) 962-6511 ext. 6965	Implements and manages DOD hazardous waste disposal programs
U.S. Air Force		
HQUSAF Attn: LEEVP Room 5D-485 The Pentagon Washington, D.C. 20330	(202) 695-2889	Provides policy guidance and direction for the Air Force
HQAF Air Force Engineering Services Center (AFESC)/DEV Tyndall Air Force Base, Florida 32403	(904) 283-6232	Serves as technical consultant to all Air Force operations and coordinates Installation Restoration (IR) and Resource Conservation and Recovery Act programs
Engineering & Services Lab Environics Division HQ AFESC/RDV Tyndall Air Force Base, Florida 32403	(904) 283-2097, 4297	Performs research and development

Table C-1. Military Hazardous Waste Contacts (Continued)

Organization	Phone	Responsibility
Air Force Medical Services Center AFMSC/SGPA Brooks Air Force Base, Texas 78235	(512) 536-2462	Provides policy guidance and direction concerning bioenvironmental engineering consulting and laboratory services for the Air Force, and develops health and environmental standards as needed
Air Force Regional Civil Engineers (AFRCE) ER/ROV 526 Title Building 30 Pryor Street, S.W. Atlanta, Georgia 30303	(404) 221-6771	Coordinates with installations and Federal, state, and local regulatory agencies; provides engineering and construction services
HQAFLC/DEPV Department of the Air Force Wright-Patterson Air Force Base, Ohio 45433	(513) 257-4920	Develops LOGISTICS-specific policy and ensures compliance; provides AF interface with DLA/DPDS
U.S. Army		
Office of the Deputy for Environment, Safety, & Occupational Health Attn: SAILFM The Pentagon Rm. 3E-609 Washington, D.C. 20310	(202) 695-7824	Provides policy guidance and direction for the Army
U.S. Army Material Development and Readiness Command Army-DARCOM Attn: DRCIS-A 5001 Eisenhower Ave. Alexandria, Virginia 22333	(202) 274-8122	Manages DARCOM environmental programs and establishes DARCOM-specific policies
U.S. Army Toxic & Hazardous Materials Agency USATHAMA Bldg. 4585 Attn: DRXTH-CO Edgewood Arsenal Aberdeen Proving Grounds, Maryland 21010	(301) 671-2657	Manages Army IR program and provides research and development for DOD-wide IR problems and DARCOM-specific problems
Office of the Chief of Engineers Department of the Army Attn: DAEN-ZCE Rm. 1E-676 The Pentagon Washington, D.C. 20310	(202) 694-3434, 1163	Consults with SAIL-FM on policy guidance and provides technical guidance regarding policy implementation, as needed

Table C-1. Military Hazardous Waste Contacts (Continued)

Organization	Phone	Responsibility
Office of the Chief of Engineers (COE) Department of the Army Attn: DAEN-MPO-U Pulaski Bldg. 20 Massachusetts Ave., N.W. Washington, D.C. 20314	(202) 272-0588	Provides technical guidance regarding policy implementation, as needed
Office of the Chief of Engineers Department of the Army Attn: DAEN-RDM Pulaski Bldg. 20 Massachusetts Ave., N.W. Washington, D.C. 20314	(202) 272-0259	Coordinates COE hazardous waste research and development
USAED, Huntsville Attn: HNDAD-P P.O. Box 1600 Huntsville, Alabama 35807	(205) 895-5370	Directs the Army Pollution Abatement Program; currently has no defined hazardous waste responsibilities
U.S. Army Corps of Engineers Construction Engineering Research Laboratory Attn: CERL-EN P.O. Box 4005 Champaign, Illinois 61820	(217) 352-6511	Performs hazardous waste research and development, primarily for FORSCOM
U.S. Army Environmental Hygiene Agency (USAEHA) Attn: HSE-E Edgewood Arsenal Aberdeen Proving Grounds, Maryland 21010	(301) 671-2306	Provides engineering consulting and laboratory monitoring services to Army offices, and develops health and environmental standards, as needed
U.S. Navy		
Office of the Chief of Naval Ops. OP-451 Rm. BD-766 The Pentagon Washington, D.C. 20350	(202) 697-3639, 3689, 3688	Provides policy guidance and direction to Navy operations
U.S. Army Medical Bioengineering Research and Development Laboratory Fort Detrick Frederick, Maryland 21701		Performs environmental and health effects studies for the IR program and munition plant wastes

Table C-1. Military Hazardous Waste Contacts (Continued)

Organization	Phone	Responsibility
Department of the Navy Navy Material Command MAT-044 CP-5, Rm. 700 Washington, D.C. 20360	(202) 692-8781	Acquires and disposes of all Navy material and issues NAVMET-specific policy guidance
Department of the Navy NAVFAC Code 11228 Hoffman Bldg. II 200 Stovall Street Alexandria, Virginia 22332	(202) 325-0435	Provides engineering services and technical guidance and manages the Navy Assessment and Control of Installation Pollutants (NACIP) Program
Department of the Navy Commander, NAVFAC COD 032P Hoffman Bldg. II 200 Stovall Street Alexandria, Virginia 22332	(202) 325-9044	Coordinates NAVFAC research and development
Navy Energy & Environmental Support Activity NEESA Code 112H NCBC Bldg. 1163 Port Hueneme, California 93043	(805) 982-5322	Provides technical guidance and performs research and development
Department of the Navy NAVSUP Code 0321B Room 301 Washington, D.C. 20376	(202) 697-0825	Maintains the Navy's Consolidated Hazardous Item List (CHIL) and establishes naval storage, labeling, and packaging procedures
Department of the Navy NAVSUP Code 0422G Room 706 Crystal Plaza III (CP-3) Washington, D.C. 20376	(202) 695-1123	Coordinates disposal of all naval property, except real estate, and maintains close liaison with DLA/DPDS
Department of the Navy Naval Sea Systems Command (NAVSEA) Washington, D.C. 20362	(202) 692-5515	Responsible for technical assistance for ships' hazardous waste management
Marine Corps		
Commandant of the Marine Corps Code LFF-2 Washington, D.C.	(202) 694-1425	Provides policy guidance and direction for the Marine Corps; relies on the Navy for technical and engineering assistance

APPENDIX D. TECHNOLOGIES FOR HANDLING HAZARDOUS WASTES

Control technologies for hazardous waste management are divided into two categories: cleanup and prevention. Cleanup technologies are designed to treat hazardous wastes that have already been released into the environment, via improper disposal or poor management practices. Prevention technologies are designed to treat and dispose of hazardous wastes that are currently being generated.

D.1 CLEANUP TECHNOLOGIES (AAAS, 1979)

Current state-of-the-art cleanup measures are costly, and their benefits are uncertain. However, with the potentially high number of abandoned dump sites that may require remedial action, the development of suitable technology is a high priority.

The available types of remedial and cleanup technologies are described below. To estimate cleanup cost, a base case was used that assumed a contaminated area of 0.5 square mile, 25 feet deep.

D.1.1 Groundwater Treatment

To prevent further migration of contaminants away from a dump site, upgradient groundwater and surface water diversion or downgradient collection and treatment can be considered. These two techniques are discussed below.

D.1.1.1 Diversion of Upgradient Groundwater and Surface Water

A bentonite slurry trench, barrier wells or an infiltration gallery, and surface drains would be installed to divert water from the contaminated land mass or leachate source. The general characteristics of such a system are described below.

Characteristics	Description
State of the art	Has been applied and is well established
Depth of soil treatable	No treatment, only containment

Degree of detoxification	Close to 100 percent for the water; zero for the land. Contaminants are neither removed nor treated, but leaching is prevented.
Treatment time	Infinite
Costs for base case*	Capital Investment Barrier wells - \$1.2 million Infiltration gallery - \$2.2 million Operating Costs Wells - \$0.13 million/year Gallery - \$0.23 million/year

Hydrogeological analysis, determination of cross sections, pumping tests, and dye studies are needed before a diversion system can be designed. With the proper data base, the design of a system is straightforward, and pollutant transport can be effectively controlled.

D.1.1.2 Collection and Treatment of Downgradient Groundwater and Surface Water

A barrier system would be installed to intercept leachate from contaminated sites. Collected water would be pumped to a treatment plant, and clean water would be recharged to the aquifer. A possible treatment sequence might include filtration to remove suspended solids, carbon adsorption to remove organics, and reverse osmosis to remove inorganic ions. The general characteristics of such a system are described below.

Characteristics	Description
State of the art	Barrier system technology is available, and water treatment and subsequent recharge use standard technology.
Depth of soil treatment	None
Degree of detoxification	Eventually, all leachable components should be removed from groundwater.

---

* Assumes a contaminated land area of 0.5 square mile, 25 feet deep.

Time for decontamination	50 years to infinity
Costs for base case	Capital Investment Barrier wells - $5.9 million Infiltration gallery - $9.7 million Operating Costs - $1 million/year

Although this method is comparable in cost to incineration or wet chemical treatment, and the project lifetime is longer, it is the only state-of-the-art method that can handle both organic and inorganic contaminants. It also avoids the rather severe environmental impacts that could be associated with an excavation operation in contaminated soil. The preliminary lab and field test data required for implementation are less than for incineration, and far less than for wet chemical treatment. The degree of detoxification achieveable through interception and treatment of the groundwater should eventually approach that for treatment of excavated soils, although the times for detoxification would be longer.

D.1.2 In Situ Biological Treatment

In situ treatment of wastes has had minimal application to date. The technique requires little energy, but cleanup is slow. The various techniques available are described in the following sections.

D.1.2.1 Soil Activation

The properties of the soil (e.g., pH, oxygen content, moisture content, organic content, and temperature) would be used and enhanced to maximize its inherent capacity to degrade toxicants via chemical and biological mechanisms. The general characteristics of such a system are described below.

Characteristics	Description
State of the art	Natural soil degradation processes are well documented, and degradation of pesticides has been achieved by enhancement of a single soil parameter. This method has not been applied on a large scale, nor tested for soils contaminated with a mixture of chemical substances.

Depth of soil treatable	Approximately the top 12 inches at most
Degree of detoxification	Unknown. Organophosphate and carbonates do degrade to non-toxic products. Some contaminants may be converted to equally or more toxic products.
Time for decontamination	5 to 20 years
Costs for base case	$1.4 million

Because the method involves the stimulation of natural processes, the environmental impact should be minimal. Laboratory and small field plot tests will be necessary to determine optimum conditions for degradation of each contaminant and to establish technical feasibility for the particular contaminated area under consideration. If the method is demonstrated to have real potential for converting the contaminants to nontoxic products, it has the advantage of relatively low implementation costs. The method would not be capable of degrading contaminants lying much below a depth of 12 inches.

D.1.2.2 Vegetational Uptake

Crops capable of concentrating toxic residues from soil would be repeatedly planted, harvested, and hauled away for disposal. Incineration would be the safest method for disposal of these crops, preventing most of the toxics from being released to the ground again. The general characteristics of such a system are described below.

Characteristics	Description
State of the art	Root crops and soybeans have been shown to concentrate residues of arsenic, lead, and a number of pesticides. The method has not been applied on a large scale, or for multiple contaminants.
Depth of soil treatable	Limited to the upper 12 inches of soil, although some crops, such as alfalfa, are much more deeply rooted.

Degree of detoxification	Unknown. A few field studies have shown removal on the order of 5 percent of certain pesticide residues per harvest.
Time for decontamination	To achieve 95-percent removal of the original contaminants, 60 harvests would be needed.
Costs for base case	$60,000/harvest (exclusive of disposal costs)

It is questionable whether a soil contaminated with a multitude of toxic compounds could be significantly cleaned up by planting and harvesting vegetation. Even for those contaminants that would be taken up and translocated into the crops selected, times on the order of 60 years would be required for 95-percent removal. Furthermore, the most effective crops, from the point of view of contaminant uptake, may not be ideally suited for growth in any given contaminated area. There are also environmental risks in deliberately growing contaminated crops. Promising candidates, such as sugar beets, carrots, soybeans, and alfalfa, are used for food and forage by various domestic and wildlife species. The vegetables are eaten by man. Thus, the utmost care would be required to ensure that harvested crops are disposed of properly and are not accidentally used as food for animals or man. The low cost of this method is attractive, but the implementation problems and lack of long-term data may create too much uncertainty.

D.1.2.3 Inoculation

Large quantities of micro-organisms with a known ability to degrade specific contaminants would be incorporated into the soil. The general characteristics of such a system are described below.

Characteristics	Description
State of the art	Micro-organism technology is limited, and degradation has proven to be slow. The survivability of micro-organisms in field tests has been a problem.
Depth of soil treatable	Upper 12 inches
Degree of detoxification	Unknown
Time for decontamination	Unknown
Costs for base case	Higher than soil activation

This method is judged technically infeasible for the foreseeable future.

D.1.3 In Situ Solidification

The long-term stability and the settling rates of hazardous waste are the significant problems for in situ solidification. In addition, no specific criteria exist to determine which solidification agents perform best with which specific type of hazardous liquid or semisolid waste mixtures. Thus, solidification in situ is not considered useful in the near term.

D.1.4 Physical-Chemical Treatment and Recovery

This technology involves the actual removal of the contaminated soil with physical and chemical treatment to achieve decontamination. Because most contaminants of concern are organics, treatment methods such as carbon adsorption, neutralization, and aeration have been the most widely applied.

Wastewater treatment technology and existing mining techniques, such as solution mining, are other areas of possible technology transfer. The treatment of both groundwater and soils could be undertaken in situ. Treatment technologies that require further investigation include ion exchange processes, the use of macroreticular resins and novel selective adsorbents such as proteins, and regenerative methods for treatment agents.

D.1.5 Excavation, Treatment, and Decontamination

A contaminated site area would be excavated and treated to completely remove all contaminants. Costs for such a method would be high, and project time is long. Further research is necessary to determine the proper excavation and transport techniques needed to minimize hazardous waste release. Possible technology transfer sources are mining and dredging industries.

Soil decontamination requires further research in the treatment, solidification, and incineration aspects. Possible techniques are discussed below. The technology must be able to deal with a variety of environmental conditions at the site where the hazardous wastes were dumped. These include abandoned drums, dispersed or spilled wastes, and selective removal and treatment of hazardous constituents (i.e., heavy metals, polychlorinated biphenyls).

D.1.5.1 Incineration and Revegetation

The contaminated area would be excavated, and the soil, after coarse screening, would be fed into a rotary kiln incinerator 16 feet in diameter and 300 feet long, with a capacity of 3000 tons/day. The incinerated and sterilized soil would be returned to the test site area and restored to a condition where vegetation could again be supported. The general characteristics of such a system are described below.

Characteristics	Description
State of the art	Rotary kilns used by the cement industry have the necessary soil handling capability, temperatures, and residence times. Techniques for revegetating sterile soils are well known.
Depth of soil treatable	No restrictions
Degree of detoxification	Complete destruction of organics. Partial volatilization of arsenic, mercury, zinc, and boron. Will not remove chromium, manganese, or iron.
Time for decontamination	15 years
Costs for base case	Capital investment - $10 million Operating costs - $4.5 million/year Revegetation costs - $120,000

The method has potential for the complete removal of organic contaminants. A separate treatment step might be necessary to remove heavy metals. The environmental impact of the excavation operation could be significant. Costs are high, and the project time is long.

D.1.5.2 Wet Chemical Processing

The contaminated area would be excavated, and the soil, after coarse screening, would be slurried with water and/or solvents and passed through a two-stage chemical reaction and/or solvent extraction train. The treated slurry would be dewatered by thickeners and rotary

vacuum clarification filters, and returned to the test site area. The general characteristics of such a system are described below.

Characteristics	Description
State of the art	The existing unit processes involved in ore beneficiation and hydrometallurgy are closely analogous.
Depth of soil treatable	No restriction
Degree of detoxification	Complete, in principal, but much R&D would be required.
Time for decontamination	15 years
Costs for base case	Capital investment - $10 to $25 million Operating Costs - $3.5 million, exclusive of chemical reactants and effluent treatment train

The method has potential for the complete removal of all contaminants, but specific chemical detoxification methods (e.g., hydrolysis, neutralization, oxidation, reduction, solvent extraction) for the contaminants found to be present will have to be developed and tested. Water usage is expected to be on the order of 7000 tons/day, and the effluent control and waste disposal problems could be very severe. Costs are at least as high as those for incineration, and project time is comparable. Soil properties would be affected far less by wet chemical processing than by incineration.

D.1.6 Conclusions

Table D-1 presents, for comparative purposes, a summary of the characteristics of the previously described cleanup technologies. Upgradient diversion and downgradient treatment are the two most-proven and available technologies for cleanup and are the best short-term options. The main drawbacks to these options are that no removal of the contaminant is accomplished and, hence, treatment time may approach infinity.

Physical-chemical treatment and the two variations of excavation and decontamination (incineration and chemical processing) are based on proven technology that has not yet been successfully applied to contaminated soil and groundwater problems. Treatment times would be long

Table D-1. Summary of Hazardous Waste Cleanup Technology

Technologies	State of the Art	Depth of Soil Treatment	Degree of Detoxification	Treatment Time (yr)	Costs (million $) Capital	Costs (million $) Operating
Upgradient Diversion	Applied, established	None	0% - soil 100% - water	Infinity	$1.0-2.0	$0.1-0.3
Downgradient Treatment	Pilot	None	0% - soil 100% - water	50 to Infinity	$6.0-10.0	$1.0
Soil Activation	Studied, no applications	12 inches - maximum	Unknown	5-20	$1.4	--
Vegetational Uptake	Field studies, no applications	12 inches - depending on crop	5% per harvest	20-60	--	$0.06/ harvest
Inoculation	Laboratory testing	12 inches	Unknown	Unknown	Higher than soil activation	
In Situ Solidification	Laboratory testing	None	Variable	1-5	Low	Moderate
Physical-Chemical Treatment	Technology available, not demonstrated	Unlimited	Unknown, potentially high	1-5	Moderate	High
Excavation and Decontamination						
Incinerate/ Revegetate	Established, no applications	Unlimited	Unknown, potentially high	15	$10.0	$4.5
Wet Chemical Processing	Established, no applications	Unlimited	Unknown, potentially high	15	$10.0-25.0	$3.5

Note: Costs are based on a contaminated land area of 0.5 square mile, 25 feet deep.

and costs extremely high, but they do offer removal of the source contaminant. These alternatives may offer the best choice for mid-term applications, after some success has been demonstrated in field tests.

Soil activation, vegetational uptake, and inoculation are the least developed and tested options. Extensive development work is still required before these technologies can be considered feasible. The treatment and removal of contaminants is essentially limited to the aerobic zone of the soil profile, or approximately the upper 12 inches, and contaminant removal is very slow, resulting in long treatment times. The benefits of these technologies are that costs are minimal and disturbance to the environment is negligible. These technologies can only be considered as long-range alternatives.

D.2 PREVENTION TECHNOLOGIES

There are many competing technologies available for treating hazardous wastes for recovery and reuse or for disposal to land, incineration, or processing centers. Descriptions of the most common treatment and disposal processes follow.

D.2.1 Physical Treatment Processes (SCS Engineers, 1980; Capellini, 1980; Conway and Ross, 1980)

Physical treatment is a basic waste treatment methodology. These methods achieve the removal of contaminants based on differences in the physical properties of the contaminant and the wastewater (e.g., boiling point, specific gravity, particle size).

D.2.1.1. Sedimentation

This unit process involves the settling of suspended particles from a liquid, based on the specific gravity and settling velocity of the particle. The liquids flow through a quiescent basin of suitable dimensions to allow gravity to settle out particles of a specific size. This method is valuable as a pretreatment step to remove grit, dirt, rocks, and other inorganics that can interfere with or reduce the efficiency of other more sensitive treatment methods. The bottom sludge is then removed and dried prior to disposal.

D.2.1.2 Filtration

This process is commonly applied to gaseous or liquid hazardous wastes to remove solids prior to further treatment. Particles suspended in a fluid are separated from it by forcing the fluid through a porous medium. As the fluid passes through the porous medium, the suspended particles are trapped on the surface and/or within the body of the

medium itself. For the treatment of hazardous wastes, filtration can be used either for removing suspended solids from a liquid or for increasing the solids concentration in a sludge by removing liquid.

D.2.1.3 Separation

The differing densities of various liquids allow treatment by separation to be effective in many cases. The most widely used separation method is for oil and water mixtures. Because water is more dense than most petroleum oils, the oil can rise to the top of the mixture. Often a separation step is included in a sedimentation basin, with particles settling to the bottom and oils rising to the top of the water, where they are skimmed from the surface.

D.2.1.4 Evaporation

Evaporation is the vaporization of a liquid from a solution or a slurry to remove the volatile liquid and concentrate the nonvolatile dissolved or suspended solids or liquids. This technology can be applied only when thermal energy is available for transfer to the solution and one of the components of the solution is relatively nonvolatile. Evaporation can be used to treat both organic and inorganic wastes. In particular, for the treatment of hazardous wastes, evaporation can be used when no other treatment is currently practical (e.g., concentration of TNT); when it is preferable to other methods (e.g., concentration of radioactive wastes); when it is used as pretreatment, as an integral part of a process, or as a polishing step (e.g., spent molasses mash, dye stuff wastes, and radioactive sludges); and for complete drying of wastewaters.

D.2.1.5 Distillation

Distillation is the boiling of a liquid solution and the condensation of vapor to separate the components. The process is used to purify liquid organic streams and can produce products of any desired consistency. Vaporized components are separated, and the less volatile residual liquids or tars are removed from the system for reuse or disposal. Organic peroxides and inorganic wastes cannot generally be treated by distillation because of their explosive and nonvolatile characteristics.

D.2.1.6 Carbon Adsorption

This process removes impurities from aqueous waste streams by passing the streams through a vessel filled with carbon granules. Organics have an affinity for activated carbon, and adsorption is most useful when low concentrations of contaminants preclude the use of

conventional methods. Applications involving organic solutes work best when the solutes have a high molecular weight, low water solubility, low polarity, and low degree of ionization. Highly soluble organics (e.g., glycols) are difficult to remove because of low carbon adsorption efficiency (i.e., certain macromolecules may be too large to reach a significant fraction of the carbon's internal pores and are therefore difficult to remove). In general, strong electrolytes will not be adsorbed on carbon; some inorganic compounds (e.g., cyanide) will be adsorbed on activated carbon. However, adsorption is variable, and no general statement can be made concerning its effectiveness.

D.2.2 Biological Treatment Processes (SCS Engineers, 1980; Stover, 1980; Conway and Ross, 1980)

The basis of biological treatment processes is the use of naturally occurring micro-organisms to remove the organic contaminants from wastewater. Two simultaneous reactions take place during this process, known as oxidative assimilation and endogenous respiration. Oxidative assimilation consists of energy and synthesis reactions and involves the consumption by micro-organisms of organic material present in the wastewater. Endogenous respiration (i.e., biological oxidation) involves the energy-producing reactions in living cells. The major types of biological treatment processes used for removing organics and select inorganics are discussed below.

D.2.2.1 Activated Sludge

This process is used for both secondary treatment and complete aerobic treatment without primary sedimentation. Wastewater and recycled sludge are fed continuously into an aerated tank, where the micro-organisms metabolize and biologically flocculate the organics. Activated sludge settles from the mixed liquor under quiescent conditions. Microbial growth in the mixed liquor is maintained in the endogenous growth phase to ensure good settling characteristics. Activated sludge processes can be used to treat certain petrochemical and biodegradable organic constituents in waste streams.

D.2.2.2 Trickling Filter

This is a filter system in which the wastewater is contacted with microbial growths attached to the surfaces of the supporting media. (That is, the filter provides a surface for biological growth and voids for passage of liquid and air.) On this microbial film, soluble organics are metabolized and the colloidal organics are adsorbed onto the media surface. The biological slime layer consists of bacteria, protozoa, and fungi. Nitrifying bacteria are also frequently found here. The primary objective of the trickling filter is the conversion of biodegradable organic compounds into cell mass. All organic constituents that are not biocidal but are biodegradable can be treated.

D.2.2.3 Aerated Lagoon

An aerated lagoon is a basin in which wastewater is treated on a flow-through basis. Oxygen is usually supplied by surface aerators or diffusion aeration units. The action of the aerators keeps the contents of the basin in suspension. These contents are completely mixed, and neither the incoming solids nor the biological solids products from waste conversion are allowed to settle out. The primary function of the aerated lagoon is to convert biodegradable organic compounds into cell mass. Organic constituents that are not biocidal or resistant to degradation can be treated.

D.2.2.4 Waste Stabilization Pond

Waste stabilization ponds are relatively shallow bodies of water contained in earthen basins of controlled shape. Raw wastewater enters near the bottom at one end of the lagoon and mixes with the microbial mass of suspended solids in the sludge blanket. Excess grease floats on the liquid surface and forms a cover for the retention of heat. Excess sludge is washed out in the wastewater effluent and removed in a sedimentation basin. Waste stabilization ponds are applied to relatively dilute waste streams containing biodegradable organic compounds.

D.2.2.5 Anaerobic Digestion

This treatment process involves the biological decomposition of organic and inorganic matter in the absence of oxygen. Raw sludge from a biological treatment process is heated and circulated in a digester, and the solids are degraded by the anaerobic biological culture maintained in the digester. Anaerobic digestion is applied to all biological sludges from aerated lagoon systems, trickling filters, and activated sludge treatment processes. It is used to reduce sludge dewatering and land disposal requirements and is not a biological treatment alternative for most raw aqueous waste streams.

D.2.2.6 Land Treatment Process

This process treats wastewater by using plant cover, biological activity, soil surface, soil profile, and geological materials to remove certain wastewater pollutants. The basic operations involve uniform application of wastes to the surface or subsoil of a site; cultivation of the waste into the soil; incorporation (if necessary) of fertilizer, lime, or other additives; and periodic recultivation to ensure aerobic conditions in the soil treatment system. In this manner, the absorptive capacity of the soil can be used and some biological degradation of the wastes by soil micro-organisms can be realized. Unless the waste materials eventually decompose or weather to nondeleterious products, the entire area used for waste disposal will require covering with soil.

D.2.3 Chemical Treatment Processes (SCS Engineers, 1980; Metry, 1980; Conway and Ross, 1980)

Although biological treatment is widely applied, there are many instances that require the use of chemical approaches. These include conversion of a toxic compound to a less objectionable form, removal of traces of organic matter, oxidation of concentrated organic wastes, reduction of compounds to elemental form, and control of chemical reaction rates in liquid wastes. The major types of chemical treatment processes are discussed below.

D.2.3.1 Flocculation/Precipitation

To increase the efficiency of sedimentation basins and to remove dissolved solids, chemicals that change solubility and increase the mass of particles are mixed into the wastewater. These chemicals take contaminants out of solution and cause the suspended particles to agglomerate, making precipitation faster and more efficient. Flocculation/precipitation is widely used in wastewater treatment and is easily applied to hazardous wastes.

D.2.3.2 Chemical Oxidation/Reduction

Oxidation/reduction reactions are those in which the oxidation state of at least one reactant is raised while that of another is lowered. These reactions are applicable to both concentrated and dilute waste streams and are used primarily for treating wastes containing cyanide, phenols, organic residues, sulfur compounds, pesticides, lead, or mercury. In particular, these reactions are important because they can detoxify certain hazardous wastes, and metals can often be reduced to their elemental form for potential recycle or can be converted to less toxic oxidation states.

D.2.3.3 Hydrolysis

The term "hydrolysis" generally applies to reactions in which water brings about a double decomposition, with hydrogen going to one component and the hydroxyl radical to the other. In aqueous solutions of electrolytes, cations (anions) react with water to produce a weak base (acid). The charged species formed during hydrolytic reactions are important in the floc formation and in the treatment of turbid waters by precipitation. Hydrolysis can thus be used to yield recoverable byproducts. In addition, hydrolysis can be adapted to handle a wide variety of physical forms (i.e., gaseous, liquid, or solid organic materials). Its primary importance is in handling a wide range of aliphatic and aromatic organics such as esters, carbohydrates, sulfonic acids, halogen compounds, phosphates, and nitriles.

D.2.3.4 Liquid-Liquid Solvent Extraction

In this process, one or more impurities are removed from the wastewater by intimate contact with a second liquid having low aqueous solubility and for which the impurities have a high affinity. Extraction occurs for relatively un-ionized species in systems where the primary forces of attraction between the solute and the solvent are not ionic. The process is generally applicable to the removal of certain organic chemicals (e.g., phenolics) from water or other solvents. Solvent extraction is used to treat waste streams primarily when material recovery is desired.

D.2.3.5 Neutralization

Neutralization is a chemical reaction between an acid and a base that produces a neutral solution. Neutralization of excessively acidic or basic wastewaters is required prior to treatment and/or discharge because bacteria and aquatic life are sensitive to both rapid pH variations and to pH levels outside the range of about 6 to 9. A proper pH adjustment is also required to prevent metal corrosion, break emulsions, insolubilize certain organic materials, and control chemical reaction rates. The reaction systems range from simple addition of liquid caustic soda, or limestone beds, to complex mixing units, and the process can be used on aqueous and nonaqueous liquids, slurries, and sludges.

D.2.3.6 Ozonation

Ozonation consists of treatment with ozone. Ozone is an extremely reactive gas and is a very strong oxidizing agent. It is used to remove noxious odors (e.g., sulfides and fermentation odors) from gaseous effluents; oxidize organics (e.g., phenols); reduce cyanide emissions to acceptable levels; and disinfect wastewaters.

D.2.4 Thermal Treatment

Destroying organic hazardous waste by thermal decomposition is a proven method for a number of chemical wastes. Thermal treatment involves subjecting hazardous waste to elevated temperatures to change its chemical, physical, or biological character or composition. Incineration, the most widely practiced form, uses flame combustion in a device to degrade thermally (oxidize) hazardous waste. Other treatment forms include pyrolysis, microwave discharge, wet air oxidation, calcination, and molten salt processes.

D.2.4.1 Land-Based Incineration (Manson and Unger, 1979; Bonner et al., 1980; Bordium and Taboas, 1980; Stretz et al., 1980; Scurlock et al., 1975; Genser et al., 1977)

To ensure that complete thermal destruction takes place during incineration, there are minimum temperature and residence time requirements that must be satisfied. In general, most solvents and oils can be incinerated at a temperature of 600°C for a residence time of 2 seconds, thereby reducing them to the most elemental compounds, i.e., water, carbon dioxide, and hydrogen chloride. More complex compounds (e.g., aromatic compounds) will usually require a temperature of 1200°C for 2 seconds for comparable destruction. All solids and some viscous liquids require lower temperature pretreatment prior to thermal destruction to ensure vaporization of the waste. Bulky polymeric, ablative, or epoxy materials may require long pretreatment residence times prior to high-temperature destruction, to ensure maximum volatilization.

There are currently five types of incinerators that have the widest applicability for hazardous waste destruction. These are discussed briefly below.

Liquid Injection Combustor -- Liquid injection combustors can be used to dispose of virtually any combustible liquid waste (liquids, slurries, sludges). They have operating temperatures ranging from 650° to 1650°C and residence times of from 1/2 to 2 seconds.

Before a liquid waste can be combusted, it must be converted to a gas. This conversion occurs inside the combustion chamber and requires the transfer of heat from the hot combustion product gases to the injected liquid. To effect a rapid vaporization, it is necessary to increase the exposed liquid surface area, usually by finely atomizing the liquid to droplets that are 40 micrometers or smaller.

Liquid waste streams may be highly viscous, which makes handling and atomizing difficult. Liquids should generally have a kinematic viscosity of 2.2×10^{-3} meters^2/second or less to be satisfactorily pumped and handled in pipes. For atomization, they should have a maximum kinematic viscosity of 1.6×10^{-4} meters^2/second. If the kinematic viscosity exceeds this value, the atomization may not be fine enough, and the resultant droplets of unburned liquid may cause smoke or other unburned particles to leave the unit.

Fluidized Bed Incinerator -- Fluidized bed incinerators can be used to dispose of solid, liquid, and gaseous combustible wastes. They consist of a refractory-lined vessel containing inert granular material through which gases are blown at a rate sufficiently high to cause the bed to expand and act as a fluid. The gases are injected through nozzles that permit flow up into the bed while restricting downflow of the bed material. Waste material is pneumatically, mechanically, or gravity fed into the fluidized bed. Normally, nonhomogeneous waste

material must be reduced in size (shredded, pulverized, etc.) to facilitate the feed system operation and permit injection, distribution, and combustion within the fluidized bed. Waste and auxiliary fuel are injected radially into the bed and reacted at temperatures from 450° to 800°C. Further reaction occurs in the volume above the bed at temperatures up to 1200°C.

Multiple Hearth Furnace -- Residence time ranges from seconds to minutes. Multiple hearth furnaces consist of a refractory-lined circular steel shell with refractory hearths located one above the other. Sludge and/or granulated solid combustible waste material normally enters the furnace by dropping through a feed port located in the furnace top. Waste grease and tars are generally fed into the furnace through side ports. Liquid and gaseous combustible wastes may be injected into the unit through auxiliary burner nozzles. The secondary fuel requirement is dependent on the water content of the waste being incinerated. Rabble arms and teeth, attached to a vertically positioned center shaft, rotate counterclockwise to spiral the waste across the face of the hearth to the drop holes. The waste drops from hearth to hearth through alternating drop holes located either along the periphery of the hearth or adjacent to the central shaft. Air and combustion products flow countercurrently to the feed from the bottom to the top of the combustion chamber. Waste residence time ranges from 15 minutes to 1-1/2 hours. The system has three operating zones: the top hearths, where feed is dried to about a 48-percent moisture content, which have a temperature of 300° to 550°C; the incineration/deodorization zone, which has a temperature of 750° to 1200°C; and the cooling zone, where the hot ash gives up heat to incoming combustion air. Exhaust gases exit at 250° to 600°C.

Rotary Kiln Incinerator With Afterburner -- Rotary kiln incinerators can be used to dispose of solid, liquid, and gaseous combustible wastes. They are cylindrical shells lined with firebrick or other refractory material and mounted with the axis at a slight slope from the horizontal. They are highly efficient because of their ability to attain an excellent mixing of unburned waste and oxygen as they revolve. Seals are extremely important in any rotating device and, for this application, potential leakage is normally controlled by maintaining the entire kiln system at a slightly negative pressure. Temperatures in the kiln range from 800° to 1200°C. Residence time may vary from a couple of seconds (gaseous wastes) to a couple of hours (solid wastes).

After leaving the kiln, the products of combustion enter the secondary combustion chamber and impinge on refractory surfaces, which causes a swirling action. An afterburner, located in the secondary combustion chamber, provides exposure of the organic vapors to a high-temperature oxidizing atmosphere to ensure vapor destruction. Gaseous or liquid fuels may be used to fire the afterburner. Temperatures ranging from 650° to 1300°C are generally required for successful operation of these devices. Depending on the type of pollutant in the gas stream, residence times ranging from 0.2 to 2.0 seconds are required for complete combustion.

Multiple Chamber Incinerator -- The multiple chamber incinerator, also known as the controlled air incinerator, is used primarily for solid waste disposal. The combustion process occurs in two refractory-lined, square (or round) cross-section chambers containing auxiliary burners: primary combustion in the ignition chamber and gaseous-phase combustion in the secondary chamber. Wastes are charged in batches by a ram feeder to the lower incinerator chamber. A controlled amount of air for incineration of the waste is introduced both below and above the waste charge in this chamber. This mode of operation produces a nonturbulent combustion environment that minimizes entrainment of particulate matter. Gases from this oxidation process pass into a second chamber, where they are reheated by a large burner and additional air is introduced, so that final combustion of all volatile or organic compounds is achieved. In the primary burner section temperatures range from 800° to 1000°C. Final combustion of all gases occurs in the secondary chamber at a temperature of 1200°C and a residence time of 2 seconds.

D.2.4.2 Sea-Based Incineration (Conway and Ross, 1980; Halebsky, 1980; Interagency Work Group, 1980)

Incineration at sea is the technical equivalent of land-based incineration, because a destruction efficiency of 99.995 percent can be achieved. An incineration ship destroys wastes away from populated areas, thereby avoiding the risk to nearby communities and reducing community opposition to its operation. In addition, the acidic stack gases that the incinerator emits can be directly dispersed over the ocean surface without the elaborate "scrubbing" that is needed for such emissions from a land-based incinerator. The Environmental Protection Agency (EPA) contends that the complete incineration of chlorinated liquid hydrocarbons, which are the only toxic wastes that EPA presently allows to be incinerated at sea, yields water, carbon dioxide, hydrogen chloride, and nitrogen, and that the ocean, because of its high chloride content, is adapted to receive large amounts of hydrogen chloride without undergoing a serious chlorine imbalance. Also, because it has a built-in bicarbonate buffering system, the ocean is able to deal with any acidity produced by the hydrogen chloride to maintain its normal pH.

D.2.5 Disposal Processes

When hazardous wastes cannot be converted to nonhazardous forms by physical, biological, or chemical treatment processes, the waste must be destroyed and disposed of in an environmentally acceptable manner. At the present time, disposal options consist of stabilization/solidification in a permanent material, burial in special geological beds, land-based incineration, sea-based incineration, and burial in licensed hazardous waste disposal sites. Discussions of each of these options follow.

D.2.5.1 Stabilization/Solidification (Thompson et al., 1979; Christensen and Wakamiya, 1980)

Hazardous wastes that have been chemically or biologically treated or incinerated usually leave a hazardous residue that must be properly disposed of. Stabilization/solidification processes are options that address the long-term fate of these wastes. The processes are capable of both solidifying the waste and binding the hazardous components, thereby rendering them immobile in the environment. The fixed waste is then part of a structurally sound material, is less difficult to handle, and is essentially impermeable to leaching. It may therefore be placed in a well-designed landfill for use in subfoundations for buildings or as subgrade material under a road or runway.

The ideal stabilization/solidification system would render all hazardous wastes chemically nonreactive and immobile. This type of complete immobilization could be obtained either by encapsulating the contaminant or including it in a stable crystalline lattice. In most hazardous wastes, metals are precipitated as amorphous hydroxides that are insoluble at an elevated pH (9 to 11). By carefully selecting a stabilization system of suitable pH, the solubility of any metal hydroxide can be minimized. Some stabilization systems take advantage of these pH-solubility relationships to contain a mixture of toxic cations. Additional immobilization could be obtained if the precipitates could be made to crystallize rather than remain as gels or amorphous compounds. Anions are typically more difficult to bind into insoluble compounds than are cations. For example, sulfates and chlorides, the two most common anions in hazardous wastes, produce few insoluble compounds. Most successful attempts at chemically stabilizing anionic materials have involved the physical encapsulation and isolation of the salts by other more insoluble materials. The major stabilization/solidification processes are discussed below.

Cement-Based Techniques -- Cement-based techniques generally use Portland cement and sludge along with certain other additives (some proprietary) including fly ash or other aggregate to form a monolithic, rock-like mass. The material can be allowed to cure before placing, but generally it is allowed to cure after placing in the disposal site. The cement-based techniques have proven successful on many heavy metal sludges. The high pH of the cement mixture tends to keep the metals in the form of insoluble hydroxide or carbonate salts. Metal ions may also be taken up into the cement matrix. Additional materials and contaminants found in sludges produce different effects in the cement-waste mixture. Materials such as asbestos, latex, metal filings, and plastic may actually increase the strength and stability of the cement-waste mixture. However, certain inorganic and organic compounds in the sludges are often deleterious to the setting and curing of the cement-waste mixture. Impurities such as organic materials, silt, clay, coal, or lignite may delay setting and curing of Portland cement for as long as several days.

Lime-Based Techniques -- Lime-based stabilization techniques generally depend on the reaction of lime with fine-grained siliceous material and water to produce a hardened material. The final material can be allowed to cure before placement in a disposal site or, as is generally done, can be allowed to cure in place.

Thermoplastic Techniques -- With these techniques, the wet waste is dried and then mixed with the thermoplastic material at an elevated temperature (i.e., T $100^{\circ}C$). The mixture solidifies as it cools, and the end product is usually containerized before being placed in a landfill.

Organic Polymer Techniques -- In this process, a monomer is added to the waste or sludge and thoroughly mixed. Next, a catalyst is added to the mixture, and the mixture is transferred to another container to harden. The polymerized material does not generally combine chemically with the waste; a spongy mass forms that traps the solid particles while permitting some liquid to escape. The polymer mass can be dried before disposal but is often buried in containers without drying.

Encapsulation Techniques -- Encapsulation is often used to describe any stabilization process in which the waste particles are coated with a binder. Here it pertains to processes in which the waste mass is actually enclosed in a coating or jacket of inert material. The most commonly used process involves the use of a polybutadiene binder for the sludge followed by application of a thin polyethylene jacket around the sludge mass.

D.2.5.2 Deep-Well Disposal (Amstutz, 1980; Conway and Ross, 1980; Staats, 1980)

Deep-well disposal is the subsurface injection of liquid wastes into permeable rock or other geological formations below potable groundwater supplies or other natural resources, such as mineral deposits, at depths as low as 12,000 feet. Underground areas receiving wastes are isolated both above and below by formations that are impermeable, so that the wastes injected are permanently confined. Once a well has been closed, it can be made permanently secure by proper plugging with concrete.

A wide range of liquid wastes are suitable for deep-well disposal:

- Dilute or concentrated waste acids
- Weak or strong alkaline solutions

- Solutions of heavy metals
- Inorganic solutions
- Hydrocarbons, including chlorinated hydrocarbons
- Toxic and other hazardous solutions
- Organic solutions, including those with high biochemical or chemical oxygen demand
- Solvents

The tolerance of deep wells for waste solutions is very wide, but the tolerance for suspended solids, in most cases, is very narrow. Removal of these solids before injection is a requirement for successful long-term disposal in most subsurface strata. A second requirement is that the viscosity of the waste solution be reasonably close to that of water.

The requirements for a suitable injection stratum include

- Isolation by impervious strata (aquicludes) from usable underground water supplies and mineral resources
- Sufficient capacity: depth, porosity, areal extent, saturation
- Sufficient permeability to accept waste at a desired rate and pressure
- Compatibility of the formation with the waste to be injected

Injection strata are generally sandstone or limestone. Aquicludes may be clays, shale, marl, crystalline limestone, siltstones, impervious sandstones, and gypsum.

D.2.5.3 Secure Landfill (Shuster and Wagner, 1980; Conway and Ross, 1980; Johnson, 1980)

If a material cannot be processed for recovery or as a source of energy, and cannot be treated for discharge to the air or surface waters, it must be disposed of in a secure landfill. A secure landfill is specially designed to keep hazardous wastes from coming into contact with air, surface waters, or groundwater. This segregation is attained through the use of thick layers of nonpermeable clay, synthetic liners, or a combination of the two. The wastes are completely surrounded by these impermeable barriers.

Generally, land disposal facilities do not accept wastes that are highly reactive, flammable, explosive, or volatile, or which are liquids or pumpable sludges. These types of wastes should first be stabilized or solidified for safe handling at the land disposal site. In addition, the following steps are recommended:

- Acids should be neutralized to raise the pH.
- Cyanide-contaminated wastes should be oxidized.
- Chromium-contaminated wastes should be reduced to convert all chromium to the trivalent form.
- Arsenic-containing wastes should be chemically treated to reduce solubility.

After the wastes have been converted to a form suitable for landfilling, they are placed in the appropriate sector to ensure that incompatible waste materials do not come in contact with one another. They are then covered daily. When the landfill is completed, it is "capped" with a layer of clay and soil for vegetation. The top is contoured to prevent ponding of rain water on the surface. This vegetated, contoured clay cover prevents storm water intrusion into the completed landfill, which could create a driving force for future chemical leachate. Analysis of all incoming wastes is made to ensure proper handling and disposal, and groundwaters and surface waters are continuously monitored to detect any leakage.

D.2.6 Assessment of Technology Options

The risks associated with hazardous wastes cannot be completely eliminated, but can be minimized to acceptable levels. Unfortunately, there is no algorithm for determining the optimum treatment and/or disposal methods for a given waste; there are only simple questions requiring complex responses. These questions have to be answered before the "best" solution is decided on:

- What is the nature of the waste?
- What are the desired characteristics of output?
- What are the technical adequacies of the treatment and disposal alternatives?
- What are the economic considerations?
- What are the environmental considerations?
- What are the energy considerations?

D.2.6.1 Treatment Processes (Capellini, 1980)

After the treatment objective (e.g., resource recovery) is established, the various treatment processes capable of doing the job must be evaluated with respect to one another. At times, several processes are used in combination (e.g., for a waste stream containing both low-molecular-weight organic and heavy metal contaminants, reverse osmosis could concentrate the heavy metals and ozonation could detoxify the organics). In any case, after the treatment (or disposal) options are determined, economic considerations will ultimately be used in making the final choice.

D.2.6.1.1 Land-Based Incineration (Manson and Unger, 1979; Bonner et al., 1980; Bordium and Taboas, 1980)

Incineration has several advantages over conventional disposal methods such as landfills: The volume and mass of hazardous waste are greatly reduced, and toxic compounds can be converted to less harmful compounds. For any incineration process, air pollutants may be formed as a result of incomplete combustion and from the products of combustion of constituents present in the fuel and oxidizer. Incomplete combustion occurs when waste constituents or their partially degraded products (e.g., hydrocarbons, polycyclic organic matter) escape thermal destruction in the incinerator. Depending on the waste material composition and combustion conditions, some end products of combustion (e.g., hydrogen chloride, hydrogen fluoride) can be formed that are also classified as air pollutants. Even though the exhaust gas generally contains relatively small concentrations of both classes of air pollutants, pollution controls must be used to further reduce these concentrations to environmentally acceptable levels. In general, organic pollutants emitted as a result of incomplete combustion of waste can be handled by continued combustion at high temperatures using afterburners; scrubbers can be used to control halogenated compounds and particulates; and filters can also be used for particulates.

Table D-2 addresses the capability of various incinerator types to handle a large range of hazardous wastes, including troublesome solid wastes. Based on the technical description of the various incinerators, the rotary kiln with afterburner and the multiple chamber incinerators appear best suited for hazardous waste operations. They are clearly the most versatile and provide the greatest capability for handling the variety of wastes and the required residence time and temperature regimes (2 seconds at 1200°C) discussed previously.

D.2.6.1.2 Sea-Based Incineration (Halebsky, 1980; Interagency Work Group, 1980)

The only hazardous wastes that have been accepted for ocean incineration by EPA are chlorinated liquid hydrocarbons. Solid, containerized waste has not yet been approved for ship incineration.

Table D-2. Wastes That Can be Handled by Incinerators Considered in This Study

	Liquid Injection	Fluidized Bed	Multiple Hearth	Rotary Kiln	Multiple Chamber
Solids:					
Granular, Homogenous		X	X	X	X
Irregular, Bulky (Tiles, Insulation, etc.)			X	X	X
Low Melting Point (Greases, Lubricants, etc.)	X	X	X	X	X
Organic Compounds With Fusible Ash Constituents			X	X	X
Unprepared, Large, Bulky Material				X	X
Gases:					
Organic Vapors	X	X	X	X	X
Liquids:					
High Organic Strength Aqueous Wastes Often Toxic	X	X		X	a
Organic Liquids	X	X		X	a
Solids/Liquids:					
Waste Contains Halogenated Aromatic Compounds	X			X	a
Aqueous Organic Sludges		X	X	X	a

a The multiple-chamber incinerator is designed specifically for solid waste disposal. The system can, however, be modified to handle liquid wastes. Tests are currently being conducted by Los Alamos Scientific Laboratory to determine how effective this system is for the thermal destruction of liquid wastes.

Dissolved, slurried, or suspended hydrocarbon wastes would essentially be considered as liquids and be acceptable for incineration; however, it would first be necessary to demonstrate that the incineration system involved met the combustion requirements. These include a 1250°C flame temperature, a minimum 1-second residence time at 1250°C, a combustion efficiency (conversion of carbon to CO_2) of greater than 99.9 percent, and a destruction efficiency of the toxic compounds of

99.95 ± 0.05 percent. Aqueous or nonaqueous organic or inorganic salts would, in most instances, not be acceptable because they usually contain heavy metals such as lead, mercury, cadmium, arsenic, and antimony.

EPA has stated that waste streams for ocean incineration are limited to part-per-million concentrations of heavy metals. The precise value of these concentrations has not been defined.

Toxic wastes that do not fall in any of the foregoing categories would have to be examined on an individual basis and the effect of their combustion products on the environment determined.

D.2.6.2 Disposal Processes

D.2.6.2.1 Stabilization/Solidification (Thompson et al., 1979; Christensen and Wakamiya, 1980)

The types of materials each process can and cannot be applied to are listed in Table D-3. As indicated, stabilization techniques vary widely in their applicability and pretreatment requirements. In selecting a process, careful consideration should be given to the degree of containment required, the cost of processing, the resulting volume, and the handling characteristics of the final product. The final selection should be made only after chemical and physical properties have been tested to ensure that the fixed sludge has the desired properties.

Table D-3. Basic Data on Stabilization/Solidification Processes

Fixation System	Major Materials Stabilized	Materials to Which System Is Not Applied
Cement-Based	Toxic inorganic industrial wastes, stack gas scrubbing wastes	Organic wastes, toxic anions
Lime-Based	Toxic inorganic industrial wastes, stack gas scrubbing wastes	Organic wastes, toxic anions
Thermoplastic	Toxic inorganic industrial wastes	Organic wastes, strong oxidizers
Organic Polymer	Toxic inorganic industrial wastes	Acidic materials, organics and strong oxidizers
Encapsulation	Toxic and soluble inorganic industrial wastes	Strong oxidizers

So far no stabilization process has been developed that is optimal or even applicable to every type of hazardous industrial waste. Most available fixation techniques were designed for use on a particular type of sludge, and application to other sludges is not always successful.

D.2.6.2.2 Deep-Well Disposal (Staats, 1980; Amstutz, 1980; Conway and Ross, 1980)

Deep-well disposal is recommended for those difficult cases where surface treatment is determined to be technically, environmentally, or economically impractical. Satisfactory disposal in most, but not all, cases is limited to liquids that are free of suspended solids or that can be filtered. The injection of hazardous wastes into deep wells can be used only in geologically selective areas where conditions below the surface are such that the wastes injected cannot migrate to pollute surface water or groundwater and reclaimable minerals. Little evidence exists of any environmental problem resulting from deep-well disposal. However, a strong commitment by government and industry is required to establish strict controls over the drilling technology used, monitor the well in the drilling and operating phases, and limit the types of substances that can be injected. Substantial geological information is needed so that only areas where wastes can be securely held are identified for site development. The following data are needed for any proposed new underground injection operation:

- Detailed engineering data on casing and cementing programs
- Map showing all wells within 2 miles
- Operating plan, pressure levels, and fluids involved
- Geologic data on injection zones and confining beds
- Underground sources of drinking water and mineral resources

D.2.6.2.3 Secure Landfill (Staats, 1980)

Burial of hazardous waste in a secure landfill is the most common disposal method used. Until a greater capacity for other disposal methods is developed for the country, land disposal will remain predominant. But eventually we will run out of land on which to develop sites. In addition, depending on location and the substances being disposed of, land disposal sites can eventually leach and contaminate groundwater. Many hazardous substances such as chlordane and benzene do not degrade except over very long periods of time. Disposing of them in a land site close to groundwater presents an almost permanent future danger. Total elimination of land disposal would not be practical. It will always be required to dispose of certain solids, such as the residues from incineration and solids that cannot be injected into deep wells.

APPENDIX D REFERENCES

AAAS, 1979, "Scientific and Technical Aspects of Hazardous Waste Management," American Association for the Advancement of Science, report from a workshop considering problems identified by the Intergovernmental Science, Engineering, and Technology Advisory Panel, College Park, Maryland, July 11-13, 1979.

Amstutz, R.W., 1980, "Deep-Well Disposal: A Valuable Natural Resource," Toxic and Hazardous Waste Disposal, Vol. 4, R.B. Pojasek, ed., Ann Arbor Science, Inc., Ann Arbor, Michigan, 1980.

Bonner, T., et al., 1980, "Engineering Handbook for Hazardous Waste Incineration," Draft, Environmental Protection Agency, Contract No. 68-03-2550, 1980.

Bordium, L.C., and A.L. Taboas, 1980, "U.S. DOE Radioactive Waste Incineration Technology: Status Review," Preprint LA-UR-80-692, presented at Waste Management 1980, Tucson, Arizona, March 11, 1980.

Capellini, A.R., 1980, "Physical Treatment of Hazardous Wastes," The Handbook of Hazardous Waste Management, A.A. Metry, ed., Technomic Publishing Co., Westport, Connecticut, 1980.

Christensen, D.C., and W. Wakamiya, 1980, "A Solid Future for Solidification/Fixation Processes," Toxic and Hazardous Waste Disposal, Vol. 4, R.B. Pojasek, ed., Ann Arbor Science, Inc., Ann Arbor, Michigan, 1980.

Conway, R.A., and R.D. Ross, 1980, Handbook of Industrial Waste Disposal, Van Nostrand Reinhold Co., New York, 1980.

Genser, J., et al., 1977, "Alternatives for Hazardous Waste Management in the Organic Chemical Pesticides and Explosives Industries," Report PB 278 059, Environmental Protection Agency, Washington, D.C., 1977.

Halebsky, M., 1980, "Ocean Incineration of Toxic Chemical Wastes," Toxic and Hazardous Waste Disposal, Vol. 4, R.B. Pojasek, ed., Ann Arbor Science, Inc., Ann Arbor, Michigan, 1980.

Interagency Work Group, 1980, "Report of the Interagency Ad Hoc Work Group for the Chemical Waste Incinerator Ship Program," Environmental Protection Agency, Department of Energy, Department of the Treasury, September 1980.

Johnson, R.A., 1980, "Secure Landfills for Chemical Waste Disposal," Toxic and Hazardous Waste Disposal, Vol. 4, R.B. Pojasek, ed., Ann Arbor Science, Inc., Ann Arbor, Michigan.

Manson, L., and S. Unger, 1979, "Hazardous Material Incinerator Design Criteria," Report PB 265 541, Environmental Protection Agency, Industrial Environmental Research Laboratory, 1979.

Metry, A.A., ed., 1980, "Chemical Treatment of Hazardous Wastes," The Handbook of Hazardous Waste Management, Technomic Publishing Co., Westport, Connecticut, 1980.

Scurlock et al., 1975, "Incineration in Hazardous Waste Management," Report PB 261 049, Environmental Protection Agency, Washington, D.C., 1975.

SCS Engineers, 1980, "Cost Comparisons of Treatment and Disposal Alternatives for Hazardous Wastes," Vol. 1, prepared for Environmental Protection Agency, EPA-600/2-80-188, December 1980.

Shuster, E.R., and L.E. Wagner, 1980, "The Role of the Secure Landfill in Hazardous Waste Management," Toxic and Hazardous Waste Disposal, Vol. 4, R.B. Pojasek, ed., Ann Arbor Science, Inc., Ann Arbor, Michigan.

Staats, E.B., 1980, Comptroller General of the United States, "Hazardous Waste Disposal Methods: Major Problems With Their Use," General Accounting Office, CED-81-21, B-201023, November 19, 1980.

Stover, E.L., 1980, "Biological Treatment of Hazardous Wastes," The Handbook of Hazardous Waste Management, A.A. Metry, ed., Technomic Publishing Co., Westport, Connecticut, 1980.

Stretz, L.A., et al., 1980, "Radioactive Waste Incineration Studies at the Los Alamos Scientific Laboratory," Preprint LA-UR-80-1408, paper presented at American Nuclear Society Annual Meeting, Las Vegas, Nevada, June 9-13, 1980.

Thompson, D.W., P.G. Malone, and L.W. Jones, 1979, "Survey of Available Stabilization Technology," Toxic and Hazardous Waste Disposal, Vol. 1, R.B. Pojasek, ed., Ann Arbor Science, Inc., Ann Arbor, Michigan, 1979.